Development of an e-learning platform to improve learning delivery in a low-resourced clinical ultrasound training setting

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Declaration

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

The dissertation includes no original papers published in peer-reviewed journals or books and four unpublished publications. The development and writing of the papers (published and unpublished) were the principal responsibility of myself and, for each of the cases where this is not the case, a declaration is included in the dissertation indicating the nature and extent of the contributions of co-authors.

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Abstract

Background/Objective: Some clinical ultrasound training programmes provide suboptimal training that result in credentialing failure. To address this failing in our low-resourced setting, an e-learning platform was designed and constructed using a participatory action research approach where clinical ultrasound trainees, e-learning developers and researchers collaborated to improve the trainees' access to learning delivery and enhancement, with the aim to eventually improve their low credentialing success rate.

Methodology: The participatory action research approach involved a mixed methodology to collect, manage and analyse data for each of Susman and Evered's cycle of enquiry steps, namely diagnosis, action planning, intervention, evaluation and reflection. The integration of instrumental and focal theories closed the practice-research gap by adding the necessary rigor to the study.

Results: The diagnosis stage revealed that the poor credentialing performance was caused by learning delivery failure that reduced the trainees' academic engagement. An e-learning platform was designed and constructed as an intervention to consolidate the current training capacity and provide trainees with new alternative access pathways to deliver learning more effectively (action planning). The e-learning platform was designed within a learner-centred, adult learning and motivational pedagogical paradigm. The evaluation of the e-learning platform intervention identified: context-specific resource savings, that all study participant groups accepted the new reality of incorporating e-learning as part of a blended learning approach and the learning access of trainees improved. Future research should focus on validating the usability of the draft e-learning platform and improvements of learning delivery and learning enhancement by initially making use of small peer groups followed by larger user-based groups (reflection).

Conclusion: Collaboration led to real practical and social change by creating a custom designed e-learning platform that changed the way clinical ultrasound trainees learn within a low resourced context. Early inclusion of the trainees as study participants led to their early adoption of the ability of a newly designed e-learning platform to firstly improve their learning delivery, then restore their academic engagement and eventually their learning enhancement, which should reflect in improved credentialing success rates.

Opsomming

Agtergrond/Doelstelling: Sommige kliniese ultraklank opleidingsprogramme bied sub-optimale opleiding, wat gelei het tot laer voltooiingsuitkomste van sekere programme. 'n e-leer platvorm was ontwerp en geskep om hierdie probleem op te los, binne die raamwerk van 'n omgewing van beperkte hulpbronne. Die e-leer platvorm was geskep deur middel van 'n deelnemende aksienavorsingsbenadering, waar die studente, die e-leer ontwikkelaars en navorsers nougeset saamgewerk het om leeraflewering en leervermoë van kliniese ultraklank studente te verbeter. Die uiteindelike doel was om die lae voltooiingsuitkomste van ons opleidingsprogram te verbeter.

Metodes: Die deelnemende aksienavorsingsbenadering het gebruik gemaak van gemengde metodes om data in te samel, bestuur en te ontleed vir elke stap van die Susman en Evered siklus, naamlik, diagnose, aksie-beplanning, intervensie, evaluering en refleksie. Die integrasie van instrumentele en fokale teorieë het gesorg dat die praktyk-navorsingsgaping doeltreffend oorbrug kon word.

Resultate: Die diagnose stap het gewys dat die waarneming van die swak voltooinguitkoms van ons program veroorsaak was deur 'n blokkasie van die leeraflewering, wat gelei het tot laer akademiese betrokkenheid van die kliniese ultraklank studente. 'n e-leer platvorm was ontwerp en geskep as intervensie om eerstens ons huidige opleidingskapasiteit te konsolideer. Blootstelling aan nuwe alternatiewe toeganklike paaie vir ons kliniese ultraklank studente het ten doel gehad om hul leeraflewering te verbeter (aksie beplanning). Die e-leer platvorm was binne 'n leerdergesentreerde, volwasselering en 'n motiverende pedagogiese paradigma ontwerp. Die evaluering van die e-leer platvorm intervensie het konteks spesifieke hulpbronbesparings geïdentifiseer. Sodoende het al die deelnemende groepe aanvaar dat e-leer deel vorm van 'n gemengde leerbenadering en dat die leertoegang vir kliniese ultraklank studente verbeter het. Toekomstige navorsing kan fokus op die geldigheid van die bruikbaarheid, leeraflewering en leervermoë verbetering van die e-leer platvorm ontwerp, deur 'n klein steekproef van opleiers te gebruik gevolg deur die evalueering van groter gebruiker-gebaseerde groepe (refleksie).

Gevolgtrekking: Samewerking en die skep van 'n nuwe e-leer platvorm wat die kliniese ultraklank student se manier van leer in ons lae hulpbronne-konteks verander het, het gelei tot werklike praktiese en sosiale veranderinge. Die vroeë insluiting van kliniese ultraklank studente as deelnemers aan die studie, het gelei tot hulle vinnige aanvaarding van die vermoë van die e-leer platvorm om hul leeraflewering eerstens te verbeter,

gevolg deur die herstel van hul akademiese betrokkenheid wat uiteindelik gelei het tot hul leerverbetering wat behoort te reflekteer is in hul toekomstige verbeterde voltooiingsuitkoms suksessyfers.

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AAA:	Abdominal Aortic Aneurysm
ACEP:	American College of Emergency Physicians
ACGME:	Accreditation Council for Graduate Medical Education
ALT:	Adult Learning Theory
AR:	Action Research
C&C:	Check and Connect Theory
CEMSA:	College of Emergency Medicine of South Africa
CUS:	Clinical Ultrasound
DVT:	Deep Venous Thrombosis
ED:	Emergency Department
eFAST:	Extended Focused Assessment of Sonography in Trauma
eLP:	e-Learning Platform
eLSC:	e-Learning Scorecard Theory
EM:	Emergency Medicine
EMSSA:	Emergency Medicine Society of South Africa
FEER:	Focused Emergency Echocardiography during Resuscitation
FMT:	Flow Motivational Theory
FSD:	Flash Storage Devices
IFEM:	International Federation for Emergency Medicine
JPEG file:	Joint Photographic Experts Group
KUK:	"Kliniese Ultraklank" (Clinical Ultrasound)
LCL:	Learner-centred Learning Theory
MT:	Motivation Theories
O&G:	Obstetrics and Gynaecology
PAR:	Participatory Action Research
PDF file:	Portable Document Format
PMPC:	Portable Mobile Phone Camera
S&E:	Susman and Evered's Cycles of Enquiry
Th1-6:	Themes One to Six
TN1-7:	Trainees One to Seven

Chapter 1
Introduction

1.1 Background

The use of ultrasound beyond the radiology domain has expanded exponentially over the last three decades. Cardiology and Obstetrics and Gynaecology were the first clinical specialties to use ultrasound as an integral part of their clinical assessment. Early cardiology pioneers developed echocardiography between the late fifties and early sixties. In 1968, Feigenbaum began the first echocardiography courses.[1] Thereafter, the use of echocardiography snowballed and is heralded as one of the top ten greatest discoveries in cardiology.[1] Ultrasound in Obstetrics and Gynaecology had a more definite beginning in 1958 with the classic Lancet paper by Ian Donald, John MacVicar and Tom Brown, where they first described the investigation of abdominal masses by pulsed ultrasound (Figure 1.1).[2] Subsequently, ultrasound use exploded as a clinical utility to the extent that ultrasound's safety and capability during pregnancy was hailed as one of the top technical advances in obstetrics.[3]

Figure 1.1 **Prototype scanner**
(Donald and Brown, 1957)

More recent technological advances resulted in compact, affordable, robust and high quality ultrasound machines that created the potential for its use beyond the domain of

the radiology suite. At first, the traditional ultrasound custodian specialties (radiology and cardiology) were fearful for the misuse of the technology by variably trained individuals, which delayed the use of ultrasound by non-traditional specialties, such as Anaesthesiology, Critical Care Medicine, Emergency Medicine and Surgery.[4] Opponents vocalised their concerns that doctors acting incorrectly on unsubstantiated misinformed scans may cause serious patient harm.[4] Eventually, the American Society of Echocardiography supported the extended use of ultrasound, but only under certain strict conditions, such as to assist in solving certain life-threatening haemodynamic disturbances if users were specifically trained in its use.[5-7] Only more recently have they loosened their stance, resulting in the rapid growth of ultrasound use by non-traditional specialties.

Although some Emergency Medicine physicians reported using ultrasound since the 1980s, the American College of Emergency Physicians (ACEP) only published a position statement in 1990 to support the performance of ultrasound by appropriately trained physicians. This statement was followed by recommendations that set out a model ultrasound curriculum in 1994.[8,9] In 2001, ACEP published the first ultrasound guidelines, followed by a more comprehensive edition in 2008.[10,11] In 2012, the Accreditation Council for Graduate Medical Education (ACGME) designated ultrasound as one of 23 core milestone competencies for Emergency Medicine physician graduates.[12] As Emergency Medicine training expanded internationally and gained traction as a newly established specialty, ultrasound was incorporated in the training curricula of specialist physicians; for instance in 2010 by the Royal College of Emergency Medicine in the United Kingdom.[13,14]

Since then many countries followed suit with South Africa registering Emergency Medicine as a new specialty in 2003 and, in 2007, awarding its first specialist Fellowship of the College of Emergency Medicine graduates. In 2009, ultrasound was incorporated in the South African Emergency Medicine specialist training curriculum as a core skill requirement backed by its own ultrasound policy guidelines document.[15,16] The International Federation for Emergency Medicine (IFEM – the umbrella organisation for all national emergency medicine societies), Ultrasound Special Interest Group, published a consensus guidance document in 2014 to standardise formal ultrasound training curricula globally, while taking cultural diversity and local challenges into consideration.[17] More recently, Emergency Medicine specialist training expanded rapidly in low-resourced settings, including many African countries. They started their own residency programmes that also included ultrasound as a core skill.[14]

Clinical ultrasound is one of several terms commonly used to refer to the use of ultrasound as a focused diagnostic test by clinicians, who are directly involved with the care of patients. Other terminologies include "point-of-care ultrasound", "bedside ultrasound", "emergency ultrasound", "focused ultrasound", and "limited ultrasound". These terms are often used interchangeably, as clinical ultrasound applies to a broad range of clinical specialties.[18,19]

Expedited and improved accuracy of patient diagnosis, more effective management of diseases and injuries, reduction of complications when used for invasive procedural guidance, significant time efficiency improvements and decreased patient care costs are some of the benefits that clinical ultrasound provide to its users and patients.[20-25] However, if the skill is used poorly without sufficient expertise, clinical ultrasound may contribute to misdiagnosis, needless downstream diagnostic testing, incorrect treatment and possible patient harm.[26] Rigorous training standards are therefore necessary to assure operator skill competency to minimise clinical errors that may result in unnecessary patient injuries.

1.1.1 Clinical ultrasound training

When considering skill uptake, three key topics must be considered. *Competence* is the recognition of a certain ability or skill; however, competence does not grant a person the credential to perform their newly acquired skill in a clinical setting. An institution grants recognition of competence through a *credentialing* process, which may be hospital, regional or national specific, and may not be transferable from one institution to another. A national body confers an *accreditation* to a specific hospital or department when a certain standard has been met. Therefore, accreditation does not usually apply to an individual. Once an individual meets the required competency level, they may be certified with an official document attesting to a level of achievement of training.[27]

Training clinical ultrasound is unique and encompasses three main learning outcomes. The first requires the combination of hands-on and cognitive skills to create optimal ultrasound images. The second is the accurate interpretation of the acquired images by identifying the relevant anatomy and pathology correctly. Finally, the third outcome is the integration of the image findings with the relevant clinical data which should lead to enhanced and more correct decision-making during the rendering of patient care.[28]

A combination of didactics and hands-on practical training has proven effective over the years.[8,29-33] Ultrasound training follows a learning curve that is initially steep and then flattens as more scanning experience is gained. For extended focused assessment of

sonography in trauma (eFAST) training, the flattening point has been described occurring at either 10, 30 or 100 scans performed by trainees depending on the training model used and the feedback quality provided.[29,32-36] The American College of Emergency Physicians (ACEP) recommends that 50 scans be performed by their trainees for each module application to reach the flattening point of the training curve.[11] In contrast, the Royal College of Emergency Medicine recommends only 25 scans to be performed.[13]

Most training programmes use the apprenticeship model, where trainees acquire their scanning experience under the direct supervision of their trainers. However, the time consuming personal instruction and feedback method creates severe conflicts within the busy work schedules of everyone involved. Clinical ultrasound includes an array of practical skills, knowledge, attitudes and values and is therefore best taught in busy emergency departments and applied to real ill and injured patients under experienced trainer guidance to expose trainees to real world clinical scenarios.

Striking this balancing act is challenging and requires the prowess of experienced trainers and clinicians to gain maximum teaching value without compromising the care of patients. Many potential teaching opportunities often go astray, where trainers are not always available when trainees are exposed to interesting cases to scan. Finding innovative image archiving techniques for indirect feedback, adapted to the time pressure and conflicts caused by patient care in busy emergency departments, may reduce these wasted teaching opportunities.

1.1.2 South African perspective

The South African clinical ultrasound curriculum mirrors the IFEM guidance document recommendations.[17] The clinical ultrasound curriculum content of the College of Emergency Medicine of South Africa (CEMSA) consist of five application modules (Table 1.1).[15,16]

Table 1.1 Five application modules of the CEMSA CUS curriculum

	Module applications
1	Extended focused assessment of sonography in trauma (eFAST)
2	Ultrasound guided central and peripheral vascular access
3	Deep venous thrombosis (DVT)
4	Abdominal aortic aneurism (AAA)
5	Basic cardiac ultrasound and focused echocardiography evaluation during resuscitation (FEER)

The application modules are delivered via the following three phases (Figure 1.2).[15,16] Each phase must be completed before progression to the next phase is allowed (Appendix A)

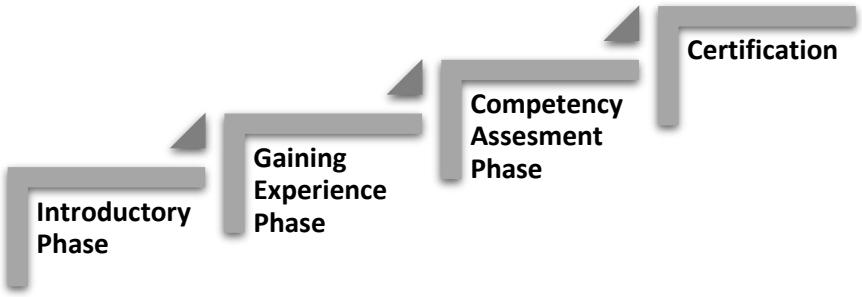

Figure 1.2 **Curriculum delivery phases to pave the way to successful credentialing**

- *Introductory Phase:* This phase consists of a one-day course that introduces the five module applications (Table 1.1.) by means of short lectures followed by instructor led hand-on scanning sessions. The aim of the course is to correctly demonstrate the three learning outcomes of the clinical ultrasound training programme (1.1.1. Clinical ultrasound training, second paragraph).
- *Gaining Experience Phase*: All candidates are required to complete a list of 65 proctored ultrasound scans for all five application modules combined during their own time in addition to their daily clinical duties. The list must include a combination of normal and pathological findings scans. Trainees require supervisor feedback for every scan. Only scans that meet the minimum technical quality and clinical interpretation are eligible to count towards the 65 scans. Trainees have a two-year period to complete the scan list from the introductory course date otherwise they are required to repeat the course before they are allowed to continue the list.
- *Competency Assessment Phase*: Only trainees that complete the 65 scans are eligible to qualify for the formal practical competency assessment. The assessment consists of four practical stations, where trainees scan live patients and models (including patients with pathology). Trainees must acquire a minimum standard on a task specific checklist and global rating scale for every station to pass their competency assessment successfully.

Only upon successful completion of all three credentialing phases, will a trainee be certified as a competent clinical ultrasound provider. Certification is provided by the Emergency Medicine Society of South Africa (EMSSA) and accepted by the CEMSA.[15,16] Only certified clinical ultrasound trainers are allowed to train, supervise and examine the trainees during the three phases of the credentialing process.

1.1.3 Finding a solution to our real world problem

The expansion of the use of clinical ultrasound in low-resourced settings has been sluggish, especially considering the significant benefits to users and patients.[37,38] A combination of cost to purchase, technical skill required to maintain the machine and assuring the user's skill and accuracy have all conspired to limit the application of clinical ultrasound in such settings. Providing adequate and effective training for users was deemed the greatest obstacle. A recent study showed that the majority of doctors practising clinical ultrasound in low-resourced settings have little or no formal training in its safe use, where the training need far outstrips what is currently on offer.[39]

Cape Town is no different. Training demand far exceeds capacity with introductory courses being booked out months ahead. Even worse, Cape Town's clinical ultrasound training programme returned a credentialing success rate of 19.7%, since its inception in 2009 to 2015. An urgent review of the training programme is needed to diagnose the reasons for its poor performance so that a transformation plan can be conceived and implemented to improve future credentialing success.

Creating real change will require equal buy-in from all stakeholders (including trainees) in the process of change itself. Action research merges the practical (alleviating the real world problem of Cape Town's poor credentialing performance), the change processes of participants and research paradigms into a singular methodological praxis of theory and practice.[40,41] Action research empowers the participants in the study (researchers and trainees), maximises collaboration through equal participation, creates the opportunities for the acquisition of new knowledge and eventually leads to social change, while solving a real world problem.[41]

The current study used a mutual collaborative approach between the study participant groups that fit the participatory action research mode of action research. Participatory action research follows an iterative, collective, collaborative, self-reflective, critical and systematic method of enquiry.[41,43] However some tensions exist in participatory action research. Somekh (2006) describes participatory action research a powerful systematic intervention that reconstructs and transforms existing practices by the centrality of human action. Therefore, the knowledge created is personalised and contextualised.[44] In contrast philosophers such as Gadamer (1960) argues that real truth cannot be explained by the imprisonment of scientific methods but rather by a return to practical philosophies.[45] Participatory action research lends itself to the investigation of individuals in personal, in-depth detail to achieve unique understanding of their real world problem

and how to solve it by bringing about real practical change. This ideographic research approach creates more complete and global understanding, however, the study findings may not be generalisable beyond the study's setting.

Our study used Susman and Evered's iterative cycle(s) of enquiry to underpin the participatory action research process to find a solution to our trainees' poor credentialing performance (Figure 1.3).[46]

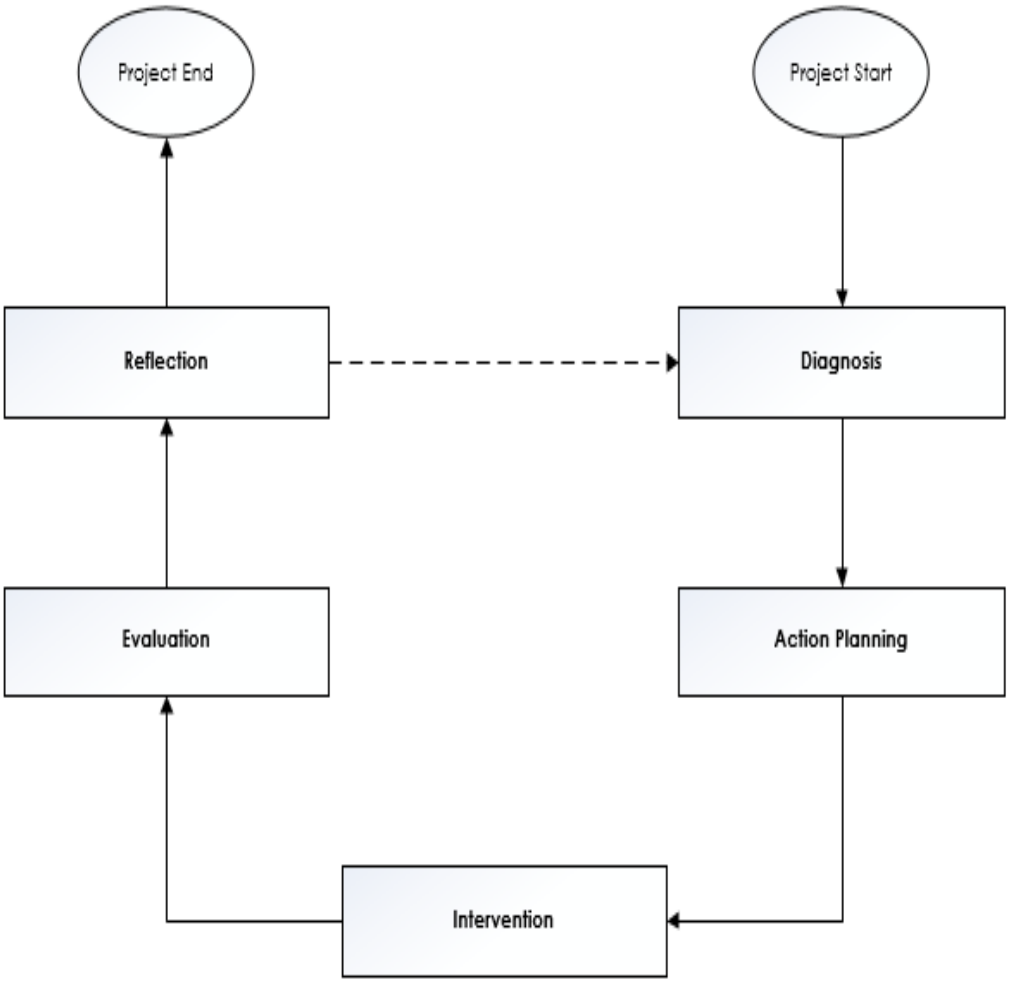

Figure 1.3 **Participatory action research module based on Susman and Evered's cycle of enquiry (1978)**

1.1.4 Research aim

The research aim was to alleviate the problem of the poor credentialing success rate of Cape Town's clinical ultrasound training programme in a low-resourced setting, by using a participatory action research approach with mutual collaboration between researchers, trainees and service providers.

1.2 Methodology

Our study followed a participatory action research approach guided by Susman and Evered cycle's steps of enquiry (Figure 1.3).[46]

1.2.1 Perspective

My interpretivist paradigm approach shared the following beliefs about the nature of knowing and reality. My relativist ontological perspective assumed that my reality was constructed intersubjectively through the meanings and understandings developed during the action research project experientially and socially. My subjectivist epistemology perspective assumed that I am not able to separate myself from what I know. My role as primary investigator and my object of investigation (action research project) are interlinked such that who I am and what my understanding of the world is forms a central part of how I understand myself, others and the world.[47]

As researcher, I also had an insider (certified clinical ultrasound trainer and emergency medicine physician providing clinical ultrasound training) and stakeholder (Director for Cape Town's clinical ultrasound training programme) perspective and relationship with the other study participants. My insider view added richness towards the interpretation of the findings of the study that aligned well with the participatory action research methodological principals of equal collaboration between researchers and participants with the view to create change while solving our real world problem.

1.2.2 Context

Cape Town is a city of 3.75 million inhabitants and is located near the southernmost point of South Africa.[48] Despite being a popular tourist destination, it is also one of the most violent cities in the world.[49] Although apartheid officially ended 22 years ago, its legacy still continues for the majority of the population. Segregated black and coloured informal settlements (townships) that originated from the apartheid era still continue to expand, fuelled by the migration influx from the Northern provinces and African countries.

Severe overcrowding, unemployment, poverty, poor access to services is a daily reality for most inhabitants.[49] Substance abuse that fuels a high occurrence of interpersonal violence, infectious diseases (including human immunodeficiency virus, tuberculosis, sepsis and infant diarrhoea) and malnutrition are common presentations to the emergency departments that serve these communities.[28,50] The Western Cape Provincial Government heavily subsidises the cost of health care so that patients, who are not able to afford it, receive medical care at no cost.

The participants of the study (researchers and clinical ultrasound trainees) worked in the emergency departments of the public hospitals that served these communities during the time of the study. Only emergency departments that hosted emergency medicine specialist trainees (registrars or residents) from Stellenbosch University and University of Cape Town were included in the study. These emergency departments are nearly always overcrowded caused by the sheer number of patient presentations, the acuity of the injuries and illnesses they presented with, and low doctor to patient ratios. These factors frequently cause emergency department patient exit and entrance blocks that compound the overcrowding scenario even further. The high patient numbers, together with the severe resources mismatch, also causes occupational stress resulting in a taxing emotional experience on medical staff members. All these factors compete with the provision of effective clinical ultrasound training within these challenging low-resourced emergency department settings.

1.2.3 Study population, sampling, data collection, data management and analyses

Each Susman and Evered cycle step created its own data collection, sampling, management and analysis methods (Figure 1.3 and Table 1.2 on next page).[46] The first Susman and Evered step used individual interviews with trainees employing inductive and deductive analyses to provide an in-depth diagnosis of the low credentialing success of our clinical training programme (articles three and four).

The root causes of the problem diagnosed were further investigated from a logistical (article one) and trainee (article two) perspectives. Individual trainee interviews data, together with e-learning developers meetings data were used for the second Susman and Evered action planning (articles three and four) and the third action intervention steps (articles three and four). The fourth Susman and Evered evaluation step focused on the changes experienced by all participant groups after the intervention was implemented, using the trainees individual interviews and e-learning developers meetings data (article four). The fifth reflection step was constructed from a reflective journal's data on the practical outcomes of the intervention (article four) (Table 1.2 and Figure 1.4).

Table 1.2 **Data collection, sampling and analyses for each of the cycle steps of enquiry of Susman and Evered**

SUSMAN AND EVERED'S CYCLE(S)	ARTICLES	DATA COLLECTION	SAMPLING	ANALYSES
Problem Diagnosis	Article 1 Article 4	Systematic review	Studies that adhered to strict inclusion criteria	Critical analysis
	Article 2 Article 4	Electronic mail survey	Cape Town ultrasound courses attendees from 1 June 2009 to 30 June 2013	Descriptive statistics
	Article 3 Article 4	Individual interviews	Cape Town emergency medicine residents/registrars who were active participants in the CUS training programme from 2014 to 2016	Inductive thematic qualitative analysis
	Article 4	Individual interviews	Cape Town emergency medicine residents/registrars who were active participants in the CUS training programme from 2014 to 2016	Deductive qualitative analysis
Action Planning	Article 3	Individual interviews	Cape Town emergency medicine residents/registrars who were active participants in the CUS training programme from 2014 to 2016	Inductive thematic qualitative analysis
	Article 4	Individual interviews	Cape Town emergency medicine residents/registrars who were active participants in the CUS training programme from 2014 to 2016	Deductive qualitative analysis
	Article 4	Researcher notes from group meetings	Researchers and e-learning developers	Deductive qualitative analysis
Intervention	Article 3	Individual interviews	Cape Town emergency medicine residents/registrars who were active participants in the CUS training programme from 2014 to 2016	Inductive thematic qualitative analysis
	Article 4	Individual interviews	Cape Town emergency medicine residents/registrars who were active participants in the CUS training programme from 2014 to 2016	Deductive qualitative analysis
	Article 4	Researcher notes from group meetings	Researchers and e-learning developers	Deductive qualitative analysis
Evaluation	Article 4	Individual interviews	Cape Town emergency medicine residents/registrars who were active participants in the CUS training programme from 2014 to 2016	Deductive qualitative analysis
	Article 4	Researcher notes from group meetings	Cape Town emergency medicine residents/registrars who were active participants in the CUS training programme from 2014 to 2016	Deductive qualitative analysis
Reflection	Article 4	Reflective journal	First and second researchers	Deductive qualitative analysis

1.2.4 Ethics

Informed consent was obtained from all individuals in all study participant groups. Confidentiality was assured by de-identifying all interviews and group meetings transcriptions including names and data that may have threatened the anonymity of study participants. All participants were assured that they had the right to withdraw from the study at any point. They also had the right to exclude their data's inclusion to the study. The primary investigator was on occasion supported by the second investigator (outsider) when difficult ethical decisions were needed from an insider and study participant perspective. The Health Research Ethics Committee at Stellenbosch University approved the study (Ref: N13/04/056).

1.3 Sequence of article chapters and dissertation format

The chapters were written in article format to facilitate future publication outputs and should therefore also be assessed as independent entities. Some of the content of the introduction and methods sections overlapped. The steps employed by Susman and Evered's cycle ran throughout the dissertation as a central theme. Participatory action research managed to merge the practical, change and research paradigms into a singular methodological praxis of theory and practice.[43] The results of the first three article chapters fed into the fourth article, which then condensed all the results underpinned by Susman and Evered cycle's steps of enquiry (Figure 1.4).[46]

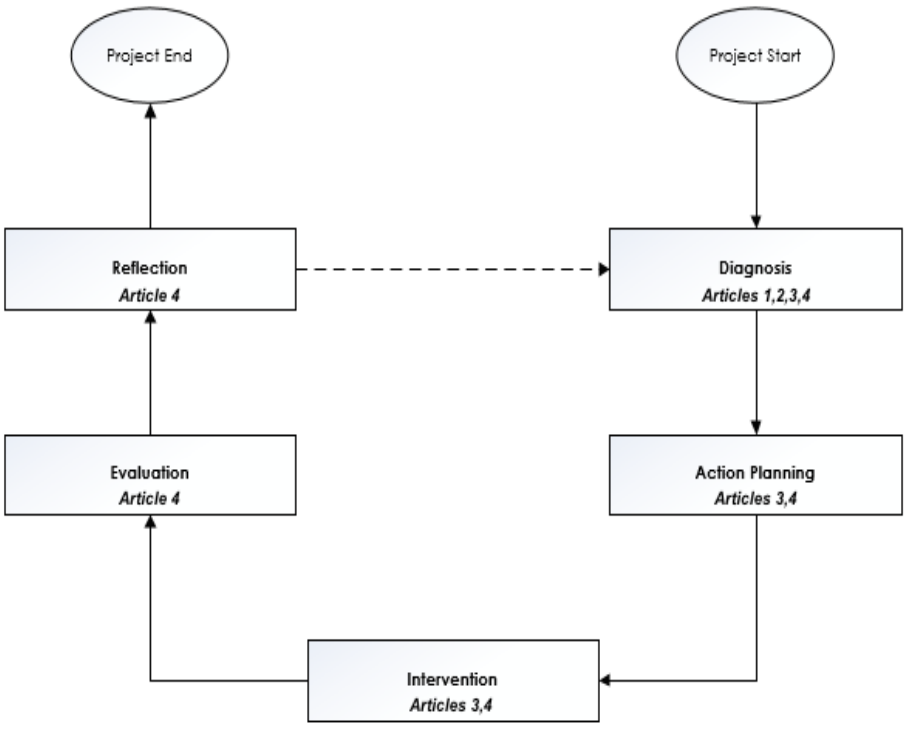

Figure 1.4 **Article chapters representing Susman and Evered's cycle steps (1978)**

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Chapter 2

Systematic review and critical analysis

2.1 Article 1: Title

Clinical ultrasound credentialing outcomes: Systematic review and critical analysis

2.2 Abstract

Background/Objective: Clinical ultrasound is widely used by physicians in all settings. Rigorous training, underpinned by well-structured credentialing, is needed to assure the accuracy of its use. The objective of the study was to critically analyse the credentialing outcomes of CUS training programmes in relation to their successes and failures, and to compare the analysis results of our own low-resourced setting's outcomes.

Methodology: A two-part study was undertaken consisting of a systematic literature review to identify credentialing outcomes of CUS training programmes worldwide, followed by a critical analysis of those outcomes in relation to a training programme offered in Cape Town, South Africa.

Results: The MEDLINE, SCOPUS and Cochrane Library search yielded 2982 studies. Six articles met the two inclusion criteria. The Cape Town Training Centre represented the only low-resourced setting. It had the lowest credentialing success rate (19.7%), followed by the United Kingdom (30.2%), Australia (33.3%), Australasia (39.1%) and Western Europe (44.9%), who delivered their training programmes over large geographical distances divided between multiple training sites. New York City (67.7%) and Massachusetts (100%) had the highest credentialing success rates. Their training programmes were well structured, highly resourced and based at single city hospital complexes that made use of fewer training sites.

Conclusions: The only low-resourced setting CUS programme had the lowest credentialing success rate. CUS programmes, that trained at multiple sites and over greater geographical distances were associated with poorer credentialing success rates.

Training programmes with lower credentialing success rates were plagued by variable learning delivery compared to their counterparts who maintained a high standard of learning delivery.

2.3 Introduction

Ultrasound performed by clinicians during the rendition of patient care improves diagnostic accuracy, provides guidance for medical procedures, enables non-invasive monitoring, is time-efficient when managing severely ill and injured patients and reduces patient care costs.[1-6] The use of clinical ultrasound expanded rapidly beyond the domain of the traditional custodian specialties of radiology, cardiology, and obstetrics and gynaecology. It is now a commonplace tool in most academic and community emergency departments. The expanse was fuelled by ultrasound machines becoming more compact, robust, and affordable and providing high definition images. However, to retain its benefits, clinical ultrasound should always be used wisely by a competent provider with sufficient expertise. If not, misinterpretation of acquired images may lead to misdiagnosis causing unnecessary downstream special investigations, incorrect patient management and possible patient injury.[7] High training standards, backed by rigorous CUS training programmes, are necessary to assure competent and certified CUS providers.

Providing effective clinical ultrasound training is resource heavy for any health system to bear. Expensive ultrasound machines and time consuming individual training, led by an instructor, are the major contributors. Training future providers to become skill competent is a prolonged undertaking that requires the combination of hands-on and cognitive skills to recognise the anatomy and pathological processes accurately.[8-14] Most clinical ultrasound training programmes are national, regional, specialty or module applications (curriculum content) based. Curriculum delivery usually occurs via an introductory course, followed by a gaining skills experience phase that consist of trainers providing feedback on trainees' scans and a final assessment of competency.[15] Upon completion, trainees usually receive a competency certificate to attest that they completed their credentialing process successfully. Given the monetary expenses and logistic challenges to provide effective curriculum delivery to clinical ultrasound trainees, inevitably varied credentialing outcomes are to be expected.

Providing clinical ultrasound in low-resourced settings is even more difficult considering the disproportionate costs and service delivery restrictions. In Cape Town (South Africa), the emergency department of public hospitals is an example of such a low-resourced

setting, where the patient load far exceeds the capacity to provide effective medical care. Unfavourable patient to medical staff ratios, disproportionately high numbers of seriously ill and injured patient presentations and insufficient equipment and consumable levels all contribute to the low-resourced setting scenario.[16,17] However, competent clinical ultrasound providers may potentially alleviate the mismatch by adding the many benefits the modality offer low-resourced settings.[18,19] Unfortunately, the clinical ultrasound trainees that have the potential to alleviate the mismatch, currently train in the same challenging low-resourced conditions, which impede their learning resulting in variable credentialing success rates.

There is no data that reports credentialing outcomes of clinical ultrasound training programmes and explores the reasons that may have contributed to their successes and failures. This information would be beneficial to directors of clinical ultrasound training programmes in all settings, who are under similar pressures to extract maximum credentialing return from the training investment made. Even more so, for low-resourced settings where they have much less training resources to invest. The aim of the study was to critically analyse clinical ultrasound training programmes credentialing outcomes in relation to their success and failures and compare the analysis results to our own low resourced setting's outcome.

2.4 Methodology

A two-part study was undertaken that included a systematic literature review to identify credentialing outcomes of clinical ultrasound training programmes worldwide and a critical review of those outcomes from the training programme offered in Cape Town, South Africa.

2.4.1 Literature review

The PRISMA-P statement of 2015 was followed to source and critically analyse relevant data for this study.[20] Searching databases and other sources identified appropriate records. Duplicate records were removed after a systematic screening process. The remaining records were assessed and included if eligible. Non-eligible records were excluded with reasons. All remaining eligible studies were included for qualitative and quantitative synthesis via critical analysis. The PRISMA-P 2015 checklist was followed to assure the necessary rigor to the comprehensive literature review process.[20]

2.4.2 Search strategy

MEDLINE, SCOPUS and the Cochrane databases were searched to identify English language articles from January 1990 (before the inception of clinical ultrasound curricula) to October 2015. The following MESH search terms were used for the MEDLINE database search:

"Ultrasonography" [Mesh] AND "Credentialing/education" [Mesh] OR "Credentialing/standards" [Mesh] OR "Accreditation/education" [Mesh] OR "Accreditation/standards" [Mesh] OR "Certification/standards" [Mesh] OR "Licensure/standards" [Mesh].

The following search terms were used for SCOPUS and Cochrane databases: ultrasonography AND credentialing OR accreditation OR certification OR licensure. Bibliographies of reviewed articles and reference lists of original research articles were also included in the review.

2.4.3 Inclusion criteria

Studies were included for analysis only if they met both the following inclusion criteria:

- Studies that reported on the clinical ultrasound training of physicians (non-radiologists), irrespective which speciality they represented.
- Studies where the credentialing or certification success rates of a training programme was reported specifically.

2.4.4 Data collection and processing

Data elements extracted directly from the studies included for summarising were: (1) first author and year; (2) title; (3) study methodology; (4) setting; (5) specialty; (6) site; (7) personnel performing ultrasound; (8) training programme details; (9) credentialing period; and (10) credentialing success rate. The data elements were compiled in table format for critical appraisal and comparison.

2.4.5 Outcome measures and data analysis

Severe heterogeneity between the different training programmes, rendered direct comparisons between their credentialing success rates unfeasible. Therefore, the primary outcome measure was to focus on the critical analyses of the credentialing outcomes of the Cape Town CUS training centre in relation to the other studies identified in the review. Simple percentage measures, calculated from trainees who entered and eventually

successfully completed their training programmes, were used to estimate credentialing success rate of a training programme.

2.4.6 Quality assessment

Retrospective studies were appraised according to Gilbert and Lowenstein criteria.[21] No studies were excluded on the risk of bias.

2.4.7 Ethics

Approval for the study was obtained from the Health Research Ethics Committee at Stellenbosch University (Ref: N13/04/056).

2.5 Results

2.5.1 Search results

The MEDLINE and SCOPUS search yielded 2 982 studies (Figure 2.1).

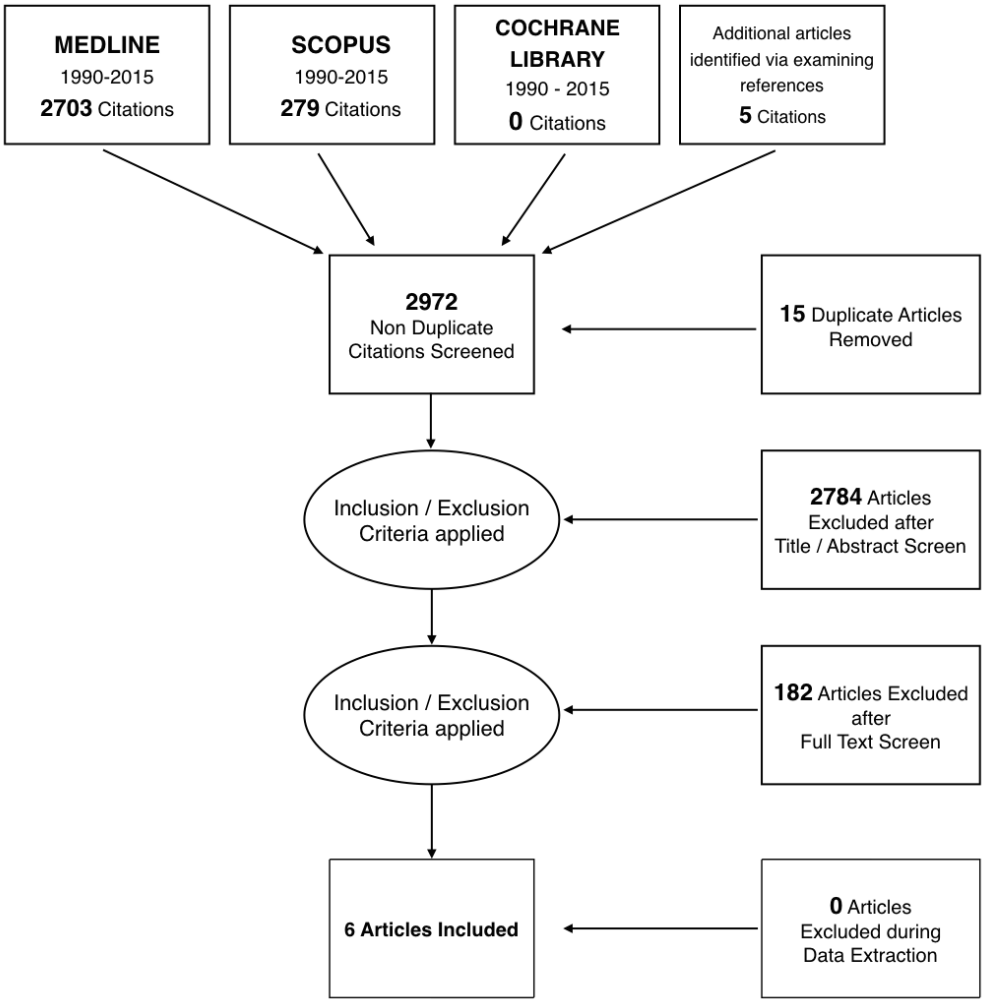

Figure 2.1 **Prisma protocol search results**

The Cochrane library search did not return any studies. An additional five articles were identified via examining the references. None eventually met any of the inclusion criteria. Fifteen duplicate articles were removed prior to the screening process. After reviewing the study titles and abstracts, 2784 studies were rejected for relevance. Of the 188 full text articles that were assessed, 182 articles were discarded not meeting the inclusion criteria while the remaining six included articles met both inclusion criteria.

2.5.2 Study characteristics

Six articles met the two inclusion criteria (Table 2.1). Of these, four were cross sectional and two were retrospective descriptive studies. The six articles represented credentialing outcomes for different specialties. Three articles reported on emergency medicine, one each for cardiology and internal medicine and one combined article for anaesthesia, emergency medicine, critical care and internal medicine. None of the six studies represented a low-resourced setting. All were conducted in high-resourced settings stationed in the United States (2), Australia (2), United Kingdom (1) and Western Europe (1). Therefore, the clinical ultrasound database analysis of Cape Town represented the only low-resourced setting within the cohort.

The timelines, when the seven studies (including Cape Town) were conducted, were misaligned. The data for the studies were collected between 2005 and 2015. Three studies trained specialist trainees (specialist in training) and already qualified specialists. The other three focused on the already qualified specialist group alone. The database of Cape Town included both specialist trainees and already qualified specialists.

The curricula content and delivery methods differed between the included studies. In the study of Fox, trainee and specialist cardiologists entered the trans-thoracic and trans-oesophageal ultrasound training programmes by registering on-line. At first they were required to pass a written exam, followed by completing a logbook of proctored scans (total scans required were unknown) within a one-year period. Upon completion, they submitted their logbook for assessment and, if successful, they received their certification.[22]

Table 2.1 **Baseline characteristics and study designs of the six selected studies and Cape Town clinical ultrasound database analysis**

First author & year	Title	Type of research	Setting	Speciality	Site	Personnel performing ultrasound	Training programme details	Creden-tialing period
Fox *et al.* [22] 2006	Report on the European Association of Echocardiography accreditations in echo-cardiography: Dec. 2003 – Sept. 2006	Experience description	Western Europe	Cardiology	Western Europe	Both trainee and qualified specialists	Registration / written assessment / complete scan logbook	1 year
Lam *et* al.[23] 2012	Hospital survey of point-of-care lung ultrasound use in the assessment of peri-operative and critical ill patients	Cross-sectional	Australia	Anaesthesia, emergency medicine, critical care medicine, internal medicine	Melbourne	Qualified specialists	Not specified	Not specified
Wright-son [24] 2012	Development and efficacy of a 1-day thoracic ultrasound training course	Experience description and cross-sectional	United Kingdom	Internal medicine and respiratory physicians (pulmonologists)	United Kingdom	Both trainee and qualified specialists	Not specified	3 months
Budh-ram et al. [25] 2013	Implementation of a successful incentive-based ultrasound credentialing programme for emergency physicians	Experience description	United States	Emergency medicine	Baystate Medical Centre, Massachusetts	Practising qualified specialists	Didactic structured lectures/hands-on sessions/complete a specified number of proctored scans/ competency assessment	2 years (4 to 6 month block for each module)
Lewiss *et al.* [26] 2013	Acquiring credentials in bedside ultrasound: a cross-sectional survey	Cross-sectional	United States	Emergency medicine	St. Luke's-Roosevelt Hospital Centre, New York City	Qualified specialists (faculty)	Complete a specified number of proctored scans (including positives) / written and practical assessment	9 months
Craig *et* al. [27] 2014	Ultrasound use in Australasian emergency departments: A survey of Australasian College for Emergency Medicine fellows and trainees	Cross-Sectional	Australasia	Emergency medicine	Australasia	Both trainee and qualified specialists	Instructional workshop / complete a specified number of proctored scans / exit assessment	Not specified
Cape Town 2016	Cape Town clinical ultrasound training database: 2009 - 2013	Experience description	South Africa	Emergency, internal, critical care medicine and surgery	Cape Town	Both trainee and qualified specialists	Introductory ultrasound course / virtual learning questionnaire / complete a specified number of proctored scans / practical competency assessment	2 years

Two studies (Lam et al. and Wrightson) did not explain their curricula content of their training programmes or their delivery methods. The survey of Lam et al. focused more on the uptake of clinicians in specifically the use of lung ultrasound within the intensive care setting.[23] The study of Wrightson examined the performance improvement in diagnostic accuracy and procedural guidance after participants (pulmonologists) completed a one-day thoracic ultrasound course. The only curriculum information extrapolated from the study was that trainees were expected to attain their credentials within three months after attending the course.[24]

Budhram et al. exposed practising qualified emergency medicine physicians to an intensive, well-structured two-year CUS training programme. The curriculum offering was extensive, focussed on eight training module applications (aorta, focused assessment of sonography in trauma, basic cardiac, renal, biliary, trans-abdominal and trans-vaginal pelvic and deep venous thrombosis) and distributed via two modules per six-month block.

Trainees were exposed to introductory didactic lectures at the start of each block, followed by weekly practical (trainer led) hands-on teaching sessions. Trainees were expected to perform and save 25 technically adequate images (still or video) for each module application, on patients in their emergency department, for asynchronous trainer review and feedback. Competency in image acquisition and interpretation were assessed for the two module applications at the end of each six-month block. Trainees achieved successful credentialing when they completed all four blocks, which included the eight required module applications.[25]

The study reported by Lewiss et al. exposed already qualified emergency medicine specialists at two hospitals to two-module applications, namely an aorta and pelvic ultrasound training curriculum. Trainees were expected to complete a training course, followed by logging 25 proctored scans for trainer review and feedback for each of the two module applications. Some scans were expected to show positive pathological findings (such as, patients with aorta aneurysms). For credentialing, trainees needed to complete a successful competency assessment that consisted of multiple-choice questions, scan images identification and hands-on assessment of the scan technique on a volunteer model.[26]

The study of Craig et al. surveyed trainee and qualified Australasian emergency medicine specialists to assess their credentialing compliance, clinical ultrasound practice and barriers to credentialing. They made use of two-module applications, namely aorta

and focused assessment of sonography in trauma. Trainees were expected to attend an instructional workshop, complete a specific number of proctored scans (number unknown) and pass an exit examination to attain their credentials.[27]

2.5.3 Analysis of outcomes

A meta-analysis (Forest plot) of the credentialing outcomes was not feasible due to the heterogeneity among the studies. Taking the methodological diversities and context-specific nature of each study into account, the bar chart in Figure 2.2 reflects the lower credentialing success rate of the Cape Town clinical ultrasound training programme, (n=218, 19.7%), in relation to the six studies included in the review.

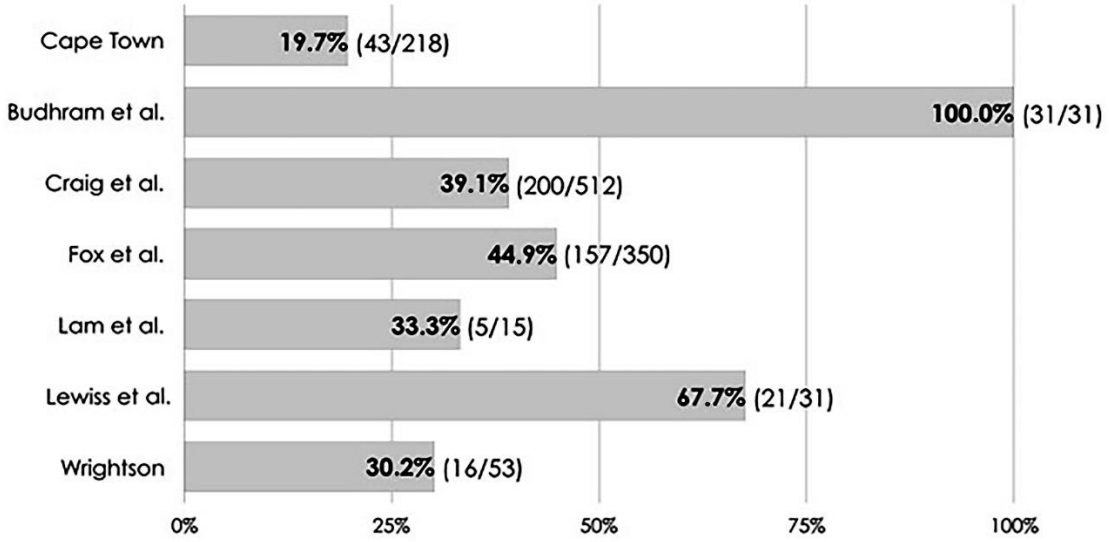

Figure 2.2 **Credentialing success rates of Cape Town study and selected studies**

2.6 Discussion

2.6.1 Less successful programmes

Four studies (Craig, Fox, Lam and Wrightson) and Cape Town's credentialing success rates were lower than the two studies in the United States (US) of Budhram at al. and Lewiss et al. (Figure 2.2).[22-24,27] The low credentialing success rates groups had some logistic challenges in common. Firstly, they all trained over large geographical distances. For example, Craig et al. and Lam et al. trained nationally in Australia, Cape Town for the Western Cape Province, Fox et al. for Western Europe and Wrightson for the whole of the United Kingdom. All four programmes offered the same training programme at multiple training locations that resulted in large scale duplication to provide a consistent curriculum delivery across the various training platforms. Many of these duplicated training centres reported a high variance of training standards among them. Two of the

studies in the group reported a lack of mentorship at some satellite training sites resulting in loss of training momentum and lack of providing adequate role models for the trainees.

However, many possible confounding factors should also be considered. There were variations in the volume of the curricula and the technical difficulty required to achieve credentialing. For example, Fox et al. trained cardiologists in more technically difficult skills (trans-thoracic and trans-oesophageal echocardiography) and more substantive curriculum volume than the other studies.

Potential language obstacles may have influenced the credentialing outcome of some studies. Fox et al. only offered their training in English to a continental European audience of cardiologists, who use many different first languages. Unfortunately, he never measured the drop-out rate that was caused by potential language barriers.

Weaknesses in the validity of the studies may also have affected the credentialing success rates reported. The poor response rate of 48% (48/120) of the cross-sectional survey of Lam et al. and the resulting small sample (n=15), of which only five received credentials, had questionable validity by not reflecting the outcomes of the study population. In the case of the study of Wrightson, validity was undermined by significant attrition and responder bias. Initially, 146 participants completed the pre-course test, while only 129 of the participants partook the post-course test. The number dropped significantly to 53 participants who eventually responded to the 3-month post-course survey of which 16 confirmed that they successfully achieved credentialing. Craig et al. had the poorest response rate (15%) from the largest study population (3414), resulting in significant non-responder and responder biases.

2.6.2 More successful programmes

In contrast, Budhram et al. and Lewiss et al. reported the highest credentialing success rates amongst the reviewed cohort.[25,26] The 100% credentialing success rate of Budhram et al. was remarkable considering the extensive curriculum offering. His programme provided eight module applications over a two-year period (two per six months block) specifically aimed at already qualified and practicing emergency medicine physicians. This older and more established physician group are usually less motivated to conform to new skill teaching. The training programme applied a rigorous training model. The programme was structured to introduce two module applications for each six-month block via didactic lectures and ultrasound demonstrations followed by trainer supervised hands-on practice that provided real time feedback on real emergency department

patient scans. Participants were continuously motivated by the trainers to complete their 25 proctored scans within the allocated six-month time allowance so they could qualify for the block competency assessment at the end. The programme offered a remedial programme for participants who failed the competency assessment to reduce the potential dropout rate.

Lewiss et al. used an equally well structured format offering a smaller curriculum that only consisted of two module applications. The training provided was similarly rigorous. However, in addition she expected her trainees to perform and record scans with positive pathology findings (such as, patients with an abdominal aorta aneurism). This added an extra training burden, which may explain the lower credentialing success rate (67.7%) than the study of Budhram et al.[26] Both studies had fewer participants (except for Lam) than the other studies included in the review. Common logistic successes existed between the two programmes. The participants of both studies were located in close geographical proximity in one hospital. Training was offered from a singular base. This rendered close control over the respective training programmes' learning delivery to its participants. Trainers, ultrasound equipment and training aids were in abundance and concentrated within the few sites used for training.

2.6.3 Context and outcome for Cape Town

South Africa is a middle-income country with a high emergency care workload and unfavourable resource mismatch leading to all the complications that derive from severe emergency department overcrowding.[17] The current South African clinical ultrasound curriculum content and delivery methods mirror the International Federation for Emergency Medicine (IFEM – the umbrella organisation for all national emergency medicine societies) guidance document.[15,28,29] Trainees enter the training programme by attending an introductory course. Thereafter, they are required to gain the necessary experience by scanning real patients to complete their recommended proctored scan list, which include scans of patients with positive pathological findings (positive scans).

Trainees may challenge the final practical competency assessment after they completed the proctored scan list. They will successfully credential after passing their final competency assessment to become certified clinical ultrasound providers. Trainees are required to pass the final competency assessment within two years after entering the training programme. Those that fail to complete within the two-year time limit are obliged to re-enter the programme by repeating the introductory course.[28] Trainees who attended any of introductory courses from 1 June 2009 (inception) to 31 October 2013

were followed to 31 October 2015 to determine if they successfully gained their credential as ultrasound providers. Only 19.7% of trainees were successful in the six-year period, which is the lowest of the studies included in the review.

The programme in Cape Town shared most of the less successful programme logistic failures. The programme was offered over large geographical distances, using multiple training sites and was the least resourced of all the studies. Many sites had no certified trainers, while some sites had no ultrasound machines available for training. Trainees were required to travel to access instructor-led sessions and feedback on their scanning technique. The severely overcrowded emergency departments were mostly used as training settings. The emergency departments' operational ultrasound machines were the only source available for training and could therefore not always be isolated for training. Most of the interesting patients to scan that offered the best learning potential were located in the emergency departments. However, the competition created by the severely overcrowded patient care needs posed a significant conflict that undermined the learning delivery of many trainer-supervised clinical ultrasound training sessions, leading to severe time insufficiency and wasted training opportunities.

2.6.4 Making less successful programmes more successful

The two successful clinical ultrasound training programmes managed to execute their learning delivery much more efficiently than their counterparts. Seamless learning delivery enabled the trainees' learning enhancement, which in turn improved their credentialing success. The less successful programmes had variable access block logistic challenges (long distances, multiple training sites and poor access to trainer instruction) that conspired to undermine their learning delivery and therefore disabled the learning enhancement of the trainees.

Learning delivery refers to the accessibility of the trainees to the training programme's learning outcomes, learning expectations, information, personalised instruction, feedback, curriculum content and accountability.[30-32] Learning enhancement is the desired effect of a well-executed learning delivery model. Learning enhancement refers to how trainees learn by relating new learning to past experiences, linking learning to specific needs and by practically applying learning, resulting in more effective learning experiences. The effects are greater learner interactivity, efficiency, motivation, cognitive effectiveness and flexibility of learning style, which all contribute to better outcomes.[33]

Less successful programmes with access block logistical challenges should focus on improving their learning delivery by supplementing their current traditional clinical

ultrasound hands-on training offering with alternative models. Intermediary courses, finishing schools and e-learning have all been used successfully in medical education to improve learning delivery, also in clinical ultrasound education. Successful integration of e-learning with the traditional hands-on clinical ultrasound training model has already revealed improved skill proficiency when performing certain ultrasound guided clinical procedures.[34] However, which supplementary tools to select to improve learning delivery will depend on the context and logistic challenges of the training programme itself.

2.6.5 Limitations

All the studies included were observational, retrospective or cross-sectional designs. Some studies suffered from low participation rates (small samples) while others had low response rates that contributed to both responder and non-responder bias. However, some descriptive studies investigated involved more representative study populations. The descriptive study designs of Budhram et al. (n=31) and Fox et al. (n=350) offered a more accurate measure of credentialing outcomes of their respective study populations than the four cross-sectional studies. Unfortunately, no experimental or prospective studies were available for inclusion. The heterogeneity meant that the credentialing success rates could not be directly compared. It is also important to note that achieving credentialing success does not always reflect a perfect competence level. More rigorous training programmes may report less credentialing success, nevertheless, their trainees may be very competent. The *visa versa* may also be true for less rigorous training programmes. A recommendation for dealing with this complex matter is to strengthen a more holistic reflection on and the assessment of credentialing success rates by using a balanced set of research methodologies.

This review article added significantly to the current discussion by quantifying credentialing success rates of different clinical ultrasound training programmes in relation to the various learning delivery models used. Understanding the interactions and relationships among each programme's unique context, credentialing success rate, and its strengths and weaknesses from a logistics perspective is essential before solutions can be sought and implemented. Future research should focus on identifying, analysing and synthesising the barriers that prevent credentialing from a trainee perspective. Problem diagnosis that derives from different perspectives will lead to more effective action planning and the creation of novel interventions to improve future credentialing yields within our unique low-resource context.

2.7 Conclusion

The only clinical ultrasound programme located in a low-resourced setting had the lowest credentialing outcome success. Clinical ultrasound programmes that provided training at multiple sites and over greater geographical distances were also associated with poorer credentialing success. Training programmes with lower credentialing outcomes were plagued by variable learning delivery compared to their counterparts who could maintain a high standard of learning delivery.

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Chapter 3
Barriers causing low credentialing

3.1 Article 2: Title

Poor return on investment: Investigating barriers causing low credentialing yields in a low-resourced clinical ultrasound training programme

3.2 Abstract

Background/Objective: Clinical ultrasound is commonly used in medical practices worldwide due to the multiple benefits the modality offers clinicians and patients. Rigorous credentialing standards are necessary to safeguard patients against operator errors. The purpose of the study was to establish, analyse and synthesise the barriers that lead to poor credentialing success from the perspective of trainees within a low-resourced clinical ultrasound training programme.

Methodology: An electronic cross sectional survey was e-mailed to all trainees who attended the introductory clinical ultrasound courses held in Cape Town since its inception in 2009 to 2013. All trainees were followed until they completed their training programme in 2015.

Results: Only one fifth of the trainees (n=43, 19.7%), who entered the Cape Town training programme, credentialed successfully. Ninety (n=90, 41.3%) trainees responded to the survey. Eighty-six (n = 86) responses were included for analysis. Time constraints were the highest ranked barrier amongst all trainees. Access barriers (to trainers and ultrasound machines) were the second highest ranked amongst the non-credentialed group. A combination between access and logistic barriers (e.g. difficulty in finding patients with pathology to scan) were the second highest ranked in the credentialed group.

Conclusions: Access barriers conspire to burden the Cape Town clinical ultrasound training programme. Novel solutions are necessary to overcome these access barriers to improve future credentialing success.

3.3 Introduction

The benefits of clinicians using ultrasound at the point of patient care have been well proven over the past 20 years.[1-3] Clinicians are now able to produce additional diagnostic information at the patient's bedside that is not accessible by physical examination alone. The benefits are enhanced in low-resourced countries where special investigations access is significantly restricted.[4] However, if clinical ultrasound is used poorly it has the potential to contribute to misdiagnosis, needless downstream testing or treatment, and possible patient harm. Rigorous training is necessary to assure competency amongst clinical ultrasound providers and to reduce operator errors that may lead to adverse events for the patient. Internationally, many clinical ultrasound training programmes currently exist, with slight variations in curricular content and delivery methods.[5,6]

In 2014, the International Federation for Emergency Medicine (IFEM) Ultrasound Special Interest Group published guidelines on how such a curriculum should be structured.[7] Nearly all-training programmes follow the IFEM recommendations of starting with an introductory course, followed by completing a hands-on proctored scan list on real patients, and finally a competency assessment to complete the credentialing process.[7] Certification should be provided to all successful candidates.

South Africa, a middle-income country with low resources to provide adequate healthcare, has a similar CUS training programme accredited by the Emergency Medicine Society of South Africa (EMSSA) and College of Emergency Medicine of South Africa (CEMSA).[8] Doctors from any specialty and level are allowed to enter the training programme by attending an introductory course. Thereafter, they are expected to gain experience by logging 65 scans on real patients, including patients with positive pathological findings (example: abdominal aortic aneurysm). Finally, trainees must pass a practical exit examination that consists of scanning live models and patients with real pathological findings. Trainees who eventually complete their credentialing are supplied with provider certificates and registered on the EMSSA web page to assure transparency of their competency status.

Training in accordance with the curriculum on the traditional apprenticeship model (where certified trainers supervise and provide real-time feedback to trainees when scanning patients during the gaining experience phase) is an expensive use of already scarce resources. The process is severely time consuming for both trainees and trainers. Trainee doctors must add the training sessions to their already busy clinical schedules.

The same challenge applies to the trainers responsible for providing feedback on the scans. Not surprisingly, recent studies identified many barriers that negatively impact on trainees credentialing success rates in both low- and high-resourced settings.[7,9-13] However, none of them analysed the type of barriers that prevent credentialing in relationship to the resources of training settings and, most importantly, their impact on the eventual credentialing success rates. A better understanding of the interaction between these important factors is necessary to bolster the current theoretical framework. Low-resourced healthcare settings have precious little resources to waste on credentialing failure.

There is a need for data that focuses on these barriers in context to the training setting and credentialing outcomes from the perspective of the trainees. A study was embarked on to establish, analyse and synthesise these barriers that specifically led to poor credentialing success rates in a low-resourced clinical ultrasound training programme. The study results provided valuable data that enhanced conceptualisation of future problem solving research questions.

3.4 Methodology

3.4.1 Study design

An electronic survey of trainees who entered the Cape Town clinical ultrasound training programme was administered. The study was conducted from October 2013 to November 2015.

3.4.2 Study setting

The attendance of the introductory course by the trainees marks their entry into the training programme. Trainees are required to pass the clinical ultrasound exit examination within a two-year period to successfully credential. Those who fail to complete their training within the required period are obliged to re-enter the programme by repeating the introductory course.[8] Cape Town is one of three national training centres responsible for providing the prescribed training curriculum that have a database of all clinical ultrasound trainees since inception of the programme on 1 June 2009.

3.4.3 Study population

All trainees, who attended the introductory course between 1 June 2009 and 30 June 2013 at the Cape Town training centre, were eligible to partake in the study. None of the

other two training centres kept databases of their course attendees. Had the information been available, it would have enhanced the sample size of this study. The survey was conducted in October 2013 and the trainees were followed until 2015 to determine whether they successfully credentialed as clinical ultrasound providers (credentialed group) or not (non-credentialed group) within the required two-year limit.

3.4.4 Data collection and management

The two hundred and eighteen trainees were invited by e-mail to complete an online questionnaire (Appendix B).

Their participation implied consent. Non-responders were reminded by e-mail at one week intervals until they responded or the survey deadline expired after one month. No personal or identifying information was collected to protect participant confidentiality. The online survey platform de-identified all responses before converting the data into an electronic spreadsheet (Microsoft Excel®, Microsoft Corporation, Redmond, WA). The electronic spreadsheet was password protected to ensure the integrity of the data. The Health Research Ethics Committee at Stellenbosch University approved the study (Ref: N13/04/056).

3.4.5 Analysis of data

Descriptive statistics were used to describe all variables. Participants were analysed according to the credentialing status (credentialed versus non-credentialed group). Their perceived barriers to credentialing were also ranked. The most important barrier for each participant received a value of 1, the second most important barrier a value of 2 and so forth until the least important barrier received a value of 7. A mean ranking score was calculated for every barrier (denominator used was the number of participants that ranked that specific barrier); the top ranked barrier would therefore have the lowest mean score (Table 3.1).

Table 3.1 **Examples to determine the rank order of barriers**

Barrier	Ranked value			Mean per barrier	Ranking
	Participant A	Participant B	Participant C		
A	1	2	No answer	1.5	1
B	2	3	No answer	2.5	3
C	3	4	3	3.3	4
D	4	1	1	2.0	2
E	No answer	5	2	3.5	5

3.5 Results

Of the 218 trainees, only 90 trainees completed the survey (response rate 41.3%). Four incomplete surveys were excluded for not ranking the barriers (Figure 3.1).

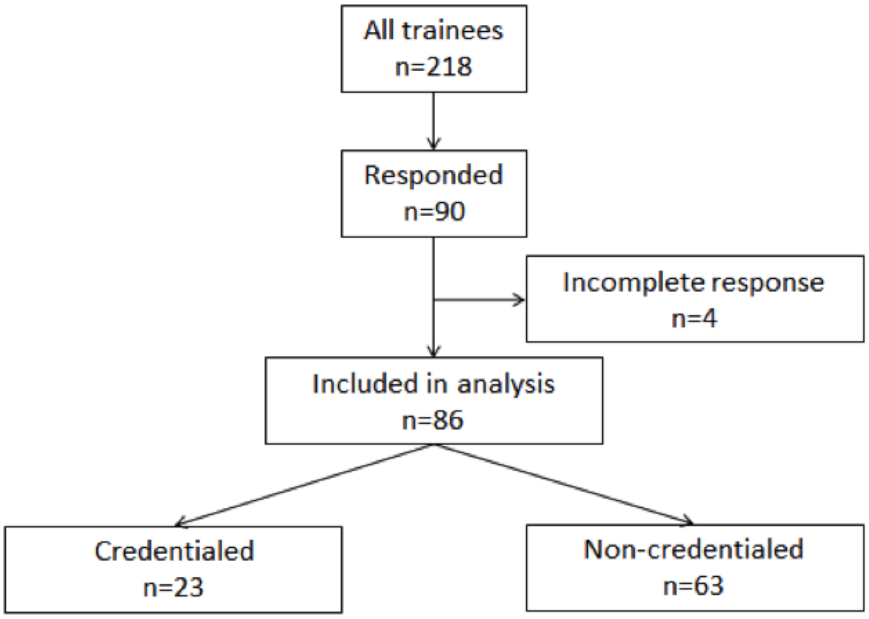

Figure 3.1 **Flow diagram of survey responses**

One fifth of trainees (n=43, 19.7%) who entered the training programme prior to July 2013 credentialed successfully: 23 of them completed the survey. The medical specialties and base hospitals of survey respondents are described in Table 3.2.

Table 3.2 **Demographics and credentialing success rate of clinical ultrasound providers participating in the study**

Variables	All n (%)	Credentialed n (%)
Medical speciality		
Emergency Medicine	59 (68.6)	23 (39.0)
Internal Medicine	10 (11.6)	0 (0)
Family Medicine	5 (5.8)	0 (0)
Other (Surgery, anaesthetics, critical care, GPs)	12 (14.0)	0 (0)
Place of work		
Central academic hospital	28 (32.6)	6 (21.4)
Regional hospital	25 (29.1)	8 (32.0)
District hospital	15 (17.4)	4 (26.7)
Other (Primary care, private practice, NC management)	18 (20.9)	5 (27.8)

GPs = General practitioners NC = Non-clinical management

All 23 successfully credentialed trainees were working in the speciality of emergency medicine; yet the credentialing success amongst the emergency medicine cohort was only 39% (registrars: n=20, 87%; junior consultants with less than five years' experience: n=2, 8.7%; senior house officers in emergency medicine: n=1, 4.3%). The greatest barrier to credentialing amongst all trainees was severe time constraints, followed by access-related barriers (such as limited trainer access) (Table 3.3).

Table 3.3 **Top three ranked barriers according to ranked mean scores**

All		Credentialed		Non-credentialed	
Rank	**Barrier**	**Rank**	**Barrier**	**Rank**	**Barrier**
1	Time constraints	**1**	Time constraints	**1**	Time constraints
2	Limited access to credentialed trainer	**2**	Difficulty to gather positive scans	**2**	Limited access to credentialed trainer
3	Difficulty to save images	**3**	Limited access to credentialed trainer	**3**	Limited access to ultrasound machine

Access barriers to trainers and ultrasound machines) were more dominant in the non-credentialed group, whereas training logistic barriers, like limited access to patients to log scans and difficulty obtaining scans with positive pathology, featured highly in the credentialed group (Figure 3.2).

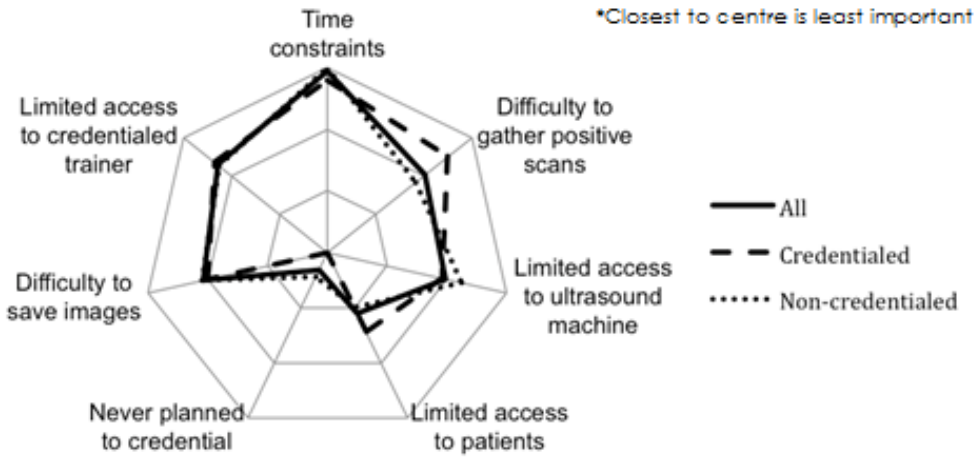

Figure 3.2 ***Perceived barriers to credentialing***

Alarmingly, 52.4% (n=33) of the non-credentialed group performed on average more than three scans per week on patients, where the scan result influenced their clinical management. However, 70% (n=44) of the same group stated they were planning to complete the credentialing process in the near future.

3.6 Discussion

The low credentialing success (19.7%) of the Cape Town clinical ultrasound training programme is very concerning, considering the time and resource investments already made. The rate is significantly lower than six peer international training programmes, whose credentialing success ranged between 30.2% and 100%. However, all six studies were conducted in high-resourced settings.[10-12,14-17] Of more concern, the credentialing success at the Cape Town centre was most likely an over estimate of the national study population, since the Cape Town sample represented 50% of the national CUS trainees but also accounted for 90% of the national credentialing success.

The higher credentialing rate in the emergency medicine cohort could be explained by the 2009 CEMSA rule that only emergency medicine specialist training doctors (registrars) whom credentialed successfully as clinical ultrasound providers are permitted to attempt the specialist training exit examinations. The ruling may also explain why only emergency medicine doctors completed the credentialing process, where 87% were registrars. However, the results also reflect a poor uptake of ultrasound training (0%) amongst more experienced (greater than 5 years) emergency medicine consultants who were never exposed to ultrasound during their specialist training.

The most significant barrier to credentialing was severe time constraints. Trainees have limited spare capacity in their current work schedules and found the additional training time burden extremely challenging. This finding concurs with two studies that surveyed comparable target populations. Australasian emergency medicine registrars and consultants reported "limited time availability" (44.5%) as their highest ranked barrier to obtain credentialing.[10] United States resident and attending emergency medicine doctors also flagged "too many other demands on time" as their greatest barrier amongst the 71.3% trainees who failed to credential in specific training programme.[12] The impact of limited access to resources on the time constraints barrier was not well described in any of the studies. To measure the positive effect on improving future time constraints when access barriers are alleviated will therefore need to be measured subjectively during future studies.

The highly ranked access barriers as perceived by the non-credentialing group concur with the findings of a survey of health workers in 44 low-resourced countries.[9] However, three studies conducted in much higher resourced settings that also trained over long distances and at multiple hospital sites, reported limited access to trainers and machines as their most important barriers after time constraints.[7,10,14-16] The three training

programmes had low credentialing success rates that varied between 30.2% to 44.9%, but still higher than that of Cape Town. Training programmes that divided their training capacity between only a few hospitals with proper trainer and ultrasound machine access had the highest credentialing outcomes that varied from 67.7% to 100%.[12,14,17] Their trainees reported finding patients with pathology to scan as their highest perceived barriers to credentialing.

Cape Town's credentialed group experienced a combination of access block to trainers and ultrasound machines and finding patients with pathology to scan, as most important. All the credentialed study participants were emergency medicine doctors. The majority of them were based at relatively well-resourced hospitals for a low-resourced setting. They had better access to trainers and ultrasound machines than their peer trainees in other specialties. Stratifying the hospital base of the doctors to their credentialing success rates suggested that higher resourced hospitals (regional and district hospitals) with better access to ultrasound machines and trainers had better credentialing outcomes (Table 3.2). Emergency medicine is a relative new specialty in South Africa, therefore, it is not yet well established at Cape Town's central academic hospitals, resulting in limited trainers and ultrasound machine availability for the trainees who were stationed there.

The finding that more than half of the participant trainees continued to perform ultrasound scans on their patients, despite not being credentialed as clinical ultrasound providers, is not unique. Two studies reported similar results regarding doctors in Australia and New Zealand.[10,18] Doctors performing ultrasound on patients without completing their credentialing open themselves to significant liability risks irrespective of the frustration the perceived barriers to training may cause them.[19] In fact, such actions are deemed as fraudulent and could result in doctors being barred from further clinical practice.[19]

The impact of the limitations of the study was reduced in accordance with the selected study design. Regular reminders were sent to bolster the participant numbers of the survey to reduce the non-responder bias impact on the results. The eventual 41.3% response rate of the survey was significantly higher than other surveys (9.6%-15%), and close to the 48% achieved by Shah et al. that targeted similar clinical ultrasound trainees study populations.[9-11] Trainees with a special interest in clinical ultrasound were probably more likely to respond, which introduced responder bias, but stratifying the respondent surveys according to their credentialing success, reduced its impact. Barriers reported by the non-credentialed group should be more reflective of the study population due to the

high percentage (80.3%) that failed to credential. The low credentialing rate amongst the non-emergency medicine doctors could be explained by the dominance of the emergency medicine representation within the training faculty and the fact that the curriculum includes both trauma- and medicine related module applications.

Training doctors to become competent in clinical ultrasound is an expensive investment for any health system to bear, even more so for a low-resourced setting. The cost of purchasing and maintaining ultrasound machines for training has direct budget implications. Providing CUS trainers from an already scarce clinician pool has a service delivery impact. Credentialing success is a measurement of return on such a relative high investment. Cape Town's training programme is burdened with low resources, multiple training centres and relative long distances between training hospitals that include rural hospitals outside Cape Town. All these circumstances conspire to exacerbate poor access to training ultrasound. Therefore, it is essential to conceive and implement novel solutions that focus on improving access to trainer feedback in a time efficient manner without adding to the high monetary and service delivery sacrifices already made.

Some trainers recommended the use of e-learning platforms to overcome the unique burdens of training ultrasound in low-resourced settings.[9] E-learning can be successfully integrated with an apprenticeship clinical ultrasound training model that is traditionally based on hands-on and simulation training.[20] The combination may result in improved skills proficiency when performing certain ultrasound guided clinical procedures if the e-learning component is introduced early enough in the training of junior residents, registrars or specialist training doctors.[20]

Future research should focus on adapting such e-learning platforms to improve overall access where trainers can provide asynchronous feedback on scans submitted by offsite trainees. The development of such a novel e-learning platform that focuses on improving credentialing success will need to be measured against its efficacy in reducing the impact of these access barriers throughout its development.

3.7 Conclusion

Limited time available to train clinical ultrasound within the busy schedules of trainees, limited access to instruction and feedback from certified trainers and limited access to ultrasound machines were the top ranked barriers that prevented the trainees to credential in our low-resourced setting. Novel solutions are necessary to overcome these

access barriers to eventually improve clinical ultrasound training programme credentialing success rates at the Cape Town facility.

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Chapter 4
E-learning platform design

4.1 Article 3: Title

Integrating clinical ultrasound trainees' experiences and requirements into an e-learning platform design to improve their learning outcomes within a low-resourced setting

4.2 Abstract

Background/Objective: Clinical ultrasound is a core emergency medicine skill. Rigorous credentialing standards are necessary to safeguard patients against operator errors. Many training programmes had poor credentialing success outcomes caused by logistic challenges and capacity mismatch to maintain the traditional and time-consuming instructor-centred apprenticeship training method. The objective of the study was to explore and integrate the understanding of clinical ultrasound trainees (future end-users) experiences and requirements within a stressful and low-resourced setting in the design of an e-learning platform (eLP) to improve their learning and eventually their credentialing success rate.

Methodology: A thematic analysis approach was used for the study. Individual interviews were conducted in two phases from November 2015 to April 2016. The first phase was exploratory and unconstructed. In Phase Two the complete study population was interviewed by using a semi-structured interview schedule that emerged from themes and codes analysed from audio transcripts of Phase One. A second level analysis explored and defined the connections between the themes to enable their reorganisation into more abstract categories that fitted with the emerging theory.

Results: Six main themes were identified. *Disenfranchised trainees* experienced varying degrees of learning delivery failure resulted in their disengagement from the training programme. *Versatile communication channels*, *improved access* to content and trainer instruction (synchronous and asynchronous) from any location on any devise and *visual benchmarking* of the quality ultrasound images expected from trainees, placed at multiple strategic locations, emerged as strategic e-learning platform design requirements. *Restoring kindredness* by accepting the trainees' contributions to forge

their own future learning and *fostering pride* in the uniqueness of the trainees patient profile exposure were added learning benefits beyond restoring the disengagement of the trainees.

Conclusion: Our study results support existing theories that advocate the use of a blended approach, where e-learning should be offered complementary to personalised instruction and not as a substitute. However, the success of the e-learning component will depend on how effectively the e-learning platform design can integrate with the trainees' context-specific requirements.

4.3 Introduction

Clinical ultrasound is a well-established core competency that enhances effective emergency medicine practice.[1-7] Rigorous credentialing standards are necessary to assure competent practitioners and protect patients against operator errors.[8] Unfortunately, delivering competency-based curricula had proven to be problematic, resulting in low credentialing success at some training centres.[9-12] One reason is the protracted process of trainees needing to perform multiple scans to become skill competent after they completed the introductory course.[13] The traditional instructor-centred apprenticeship model, where trainee doctors perform ultrasound on patients under the direct supervision of a certified trainer who affords real-time feedback, is time consuming and provides poor value for all concerned.[13] Ever increasing clinical care and medical education demands on the academic faculty results in less time available for teaching clinical ultrasound than has been the case previously.

Credentialing failure is even higher in training programmes that are low resourced, train at multiple sites and over large distances.[14] A recent study found that in Cape Town (South Africa) four out of every five doctors who entered the training programme failed to credential.[14] Their trainees ranked time constraints and access barriers to ultrasound machines and certified trainers as the most important obstacles to credentialing.[15]

E-learning (also known as web-based learning, online learning and internet-based learning) uses internet technology to deliver multiple and diverse learning modalities to improve learner knowledge and performance.[16-18] Clinical ultrasound training with its competency-based curricula that emphasise learning outcome is ideally suited for e-learning by enabling trainees to control their own learning.[19]

Some medical educators advocate to integrate e-learning by complementing existing medical curricula than opting for a stand-alone e-learning solution.[20,21] Within the

preferred blended learning approach (combining e-learning with the traditional instructor-led training), the e-learning component will improve both learning delivery and enhancement.[21] Learning delivery refers to improved access to information, curriculum content, specific learning objectives and personalised instruction.[16,17,22] Learning enhancement links to the learning experience of the trainee by practically applying their learning to real clinical scenarios. This improves the learner's efficiency, interactivity, cognitive effectiveness and motivation by personalising their experience and shifting the focus from the teacher to the learner.[16,17,22]

Some e-learning advantages can be based on adult learning theory where adults relate new learning to past experiences, by practically applying and linking their new learning to their specific needs thereby contributing to a more effective learning experience.[23] The learner-centred experience offers a stronger learning stimulus, which in turn increases the learner's engagement with the content, interactivity, means for individual practice, reinforcement and, most importantly, improved performance and motivation.[23] Learner motivation can be enhanced and cultivated further with an optimal designed e-learning platform (eLP) interface by applying certain motivation theories (such as Flow, Self-determination and Path-goal theories).[24-28] Effective integration of e-learning's benefits (content development, -management, -delivery and -standardisation) with an effective learner interface design that embrace previously mentioned learner centred theories will maximise the motivation of trainees and improve their overall outcomes.

Much evidence supports the usefulness, cost effectiveness and learner satisfaction experienced when using e-learning. In a systematic review of 76 studies, 33% reported knowledge gains and learning was at least equivalent to traditional methods and 50% demonstrated more efficient learning when e-learning was used.[29] A Canadian study reported improved skills proficiency of certain ultrasound-guided procedures after e-learning was integrated into existing training programmes.[30]

E-learning can significantly decrease costs by as much as 50%, when compared to traditional instructor-centred models thanks to savings on reduced instructor training time, travel costs, institutional infrastructure and printing and distribution of educational materials.[31] Such cost savings will be extremely beneficial for low-resourced settings. Overall, learner satisfaction increased with e-learning compared to traditional methods fuelled by individualised access navigation, interactivity and user-friendly end-user interface design.[29,31] However, for all the benefits highlighted, limited evidence exists for adapting an e-learning design to the context of training doctors in clinical ultrasound

during their rendering of emergency patient care in a highly stressful setting, especially in low-resourced settings where it is needed most.

The aim of the study was to explore and integrate the understanding of experiences and requirements of clinical ultrasound trainees (future end-users) based in a stressful and low-resourced setting in the design of an e-learning platform (eLP) to improve their learning and eventually their credentialing success.

4.4 Methodology

The thematic analysis approach was used for this study. It was particularly suited for the exploratory nature of the research problem. The researchers worked within an interpretivist paradigm, relativist ontological and subjectivist epistemology perspectives, due to the interactive and cooperative relationship between the researchers and the study participants. The first author had an insider (certified emergency physician, clinical ultrasound trainer and faculty) and stakeholder (director of the clinical ultrasound training programme) perspective and relationship with the study participants. The first author initiated the research project with the view to improve the trainees learning outcomes, conducted all the interviews and performed the data analysis. The second author assisted with the data analysis.

4.4.1 Study context and sampling strategy

The study was conducted in public hospitals in Cape Town (South Africa), as examples of low-resourced settings, which host emergency medicine residents from Stellenbosch University and the University of Cape Town specialist training programme. The training programme is conducted in severely overcrowded emergency departments with a high emergency care workload, a high ratio of seriously ill and injured patients and a low doctor-to-patient ratio.[32]

All residents, who entered the clinical ultrasound training programme by attending an accredited introductory course and actively logged any of the required 65 ultrasound scan investigations to their personalised portfolio within the last two years, were eligible to partake in the study. The trainee scans were logged under trainer-lead supervision on real hospital patients, some with pathological scan findings, within these busy emergency departments.

4.4.2 Collection of data

Individual interviews were conducted in two phases. The first phase was exploratory and unconstructed. Phase two interviewed the complete study population by using a semi-structured interview schedule that emerged from themes and codes analysed from the audio transcripts of phase one. The rationale for conducting individual interviews with the potential future end-users (trainees) was to design an eLP as part of a blended learning strategy. Considering the small study population, operating in-depth interviews was an appropriate choice to fully explore, without interference, the personal experience of each trainee (potential end-user) within the varying contexts of the different public hospitals in Cape Town.

4.4.3 Participants and procedure

During the first phase, one randomly selected study participant (from a sample of seven trainees that met the inclusion criteria for the study) was individually interviewed by asking open-ended exploratory questions about the trainees, trainers, setting, logistics and eLP design roles in improving future credentialing success (Appendix C). The first author conducted the interview in November 2015 at the trainee's Cape Town base hospital. The codes and themes were used to refine the semi-structured questions for the second phase interviews. The questions in Phase Two focused on the eLP design components that included communication improvement, educational content, end-user interface, ultrasound images upload and transfer, trainer feedback, add-ons and quality assurance (Appendix D).

The second phase interviews were conducted from December 2015 to April 2016. The sample included all seven active trainees located within the Cape Town's public hospitals domain of the study population. All interviews were conducted at the base hospitals of the participants. The interviews lasted 31 minutes on average. The same interview procedure and data recording protocol was followed throughout. At the start of all the interviews, the interviewer explained the procedure, guaranteed participant confidentiality and offered the participants the right to withdraw from the study at any point. All responses were anonymised within all the collected data sets. All participants provided written formal informed consent to the audio recording of their interviews. All seven participants received a summary that reflected the contents of their interview for member checking. Of the seven interviewees, only one suggested minor changes. The investigator kept a reflective journal from the onset to completion of the study project. The Health Research Ethics Committee at Stellenbosch University approved the study (Ref: N13/04/056).

4.4.4 Analysis of data

All audio recorded interviews were transcribed verbatim. Data analysis was conducted manually directly from the transcripts. Analysis commenced immediately after completion of the Phase One interview. All Phase Two interviews were transcribed upon their completion to allow the researchers to explore the content for possible use in subsequent interviews. The first author analysed the transcriptions assigning distinct codes to all interesting responses, including responses made in relation to the research aims of improving credentialing success (task), designing the eLP to specifically perform the task and the potential end-user expectations of the eLP beyond the task. The data analysis process strictly followed Braun and Clark's eight stages of thematic analysis.[33] Themes emerged as the growing codes were renamed, reorganised and re-categorised following complete line-by-line coding of all interview transcripts. All codes were regularly updated in the primary investigator's codebook throughout the project. Researchers kept an audit trail by strictly documenting the analysis process.

The second level analysis explored and defined the connections between the themes to enable their reorganisation into more abstract categories that fitted with the emerging theory. Data analysis was ceased when the two researchers reached consensus that no new themes or categories emerged from the raw data.

4.5 Results

4.5.1 Initial exploratory interview themes

The first phase interview was conducted in a hospital cafeteria to minimise the impact of possible interruptions and lasted 30 minutes. The interview schedule was adhered to loosely in line with the exploratory, open-ended and unstructured nature of the interview (Appendix C). Questions were asked out of order if relevant to the direction of the conversation. Seven themes emerged from the first level analysis process. The themes and codes were reworked into a more focused semi-structured interview schedule to enable us to proceed with the second phase interviews (Appendix D).

4.5.2 Semi-structured interview themes

Seven interviews were conducted between December 2015 and April 2016 at the offices of the hospitals where participants worked. The interviews ranged from 24 to 43 minutes in duration. The descriptive characteristics of the participants are shown in Table 4.1. The interview schedule was adhered to more closely than the initial exploratory interview.

Six initial themes emerged from the analysis as being dominant in the experiences and understanding of the trainees. The themes were arranged, interpreted and meaning was constructed according to the following theoretical framework, namely, credentialing (task) without an eLP (current status quo), how would the new eLP design improve the credentialing outcome and what are the trainees' expectations of the eLP beyond credentialing. Findings were supported by using verbatim quotes and are referred to as TN1-TN7 to represent the respective trainee.

Table 4.1 **Descriptive characteristics of study participants (n = 7)**

Descriptive characteristics	Values
Mean age in years (range)	34.7(12)
Gender, females	3
Year of obtaining primary medical degree (median)	2005
Mean number of months as resident in specialist training (range)	30.1(24)

4.5.3 Current trainee experiences

4.5.3.1 Theme 1: Disenfranchised trainees

Trainees experienced disenfranchisement by their strong perceptions of feeling disconnected from the training programme. Their exclusion caused them to disengage from the learning process. TN7 felt "on her own" and "dabbling in the dark". TN3 was "terrified for not knowing" of what was expected and how to engage. Trainees also felt disconnected from their trainers' mentorship. TN7 mentioned that it would be "nice to talk to somebody". TN1 agreed with the lack of mentorship experienced, "It would have been nice if somebody would take it upon themselves to be that person to help you out". The disconnection left some frustrated, as expressed by TN4, "there is always something that comes up and they are never available". However, others (TN5) understood the reality of the work burden of the trainers, "their enormous workloads prevent them from training us" and "nobody has any time because they are all so busy with our emergency department full of patients all the time"(TN1). The overwhelming effect the trainees experienced was that all trainees "felt insecure" (TN2).

Poor access to nearly all the information sources contributed to the sense of trainee disconnection from the training programme. TN2 found that "most of the information was incomplete, conflicting and distributed across different platforms". TN3 felt that "much of the information was word by mouth" and "we battled to actually find most of it". TN6 described the formal competency assessment different than the information provided beforehand. All accounts of the trainees conspired in creating confusion (TN4: "there is

always confusion") and trainee insecurity (TN7). Poor access to trainer supervision and feedback (TN1) and "I don't know who the trainers are; I'm finding out as I go along" (TN4, TN7), were also highlighted by all trainees interviewed.

Surprisingly, trainees had contrasting responses to their sense of isolation. Some reacted with defiance, circumventing the information gap to "do things on their own" (TN1) and "custom picked the training material" for self-study (TN6). They were inventive, using the Web and social media to source similar training programme content, unfortunately without any trainer academic oversight. "There was more than enough material; I only had to look for it myself" (TN6). Other trainees even felt "terrified" (TN3). Some did not have the self-belief to independently source their own teaching material. They found the multiple web sources confusing and intimidating. TN3 reflected that "there were many web sources and I did not know which ones to use". However, these compensatory measures caused them to become more isolated in their learning: marginalising them even more from the training programme, their peers and trainers. However, the only exception was TN3 who partnered with a peer trainee that was coined a "scanning buddy" with the aim to overcome the sense of fear caused by the isolation experienced.

4.5.4 Designing an eLP to improve learning

4.5.4.1 Theme 2: Versatile communication channels

Trainees reported that the eLP should provide an adaptable continuum between active and passive communication to fulfil multiple functions depending on the needs of the trainees. Variants between individuals, groups, automated and personalised communication channels should exist within such an eLP depending on the specific task at hand. The channels can be between the programme coordinator trainees and trainers, and trainers and trainees, and vice versa.

Active communication demands high attention, response and should foster communication exchange from the receiver. These active communication channels can address individuals or groups. Passive communication, on the other hand, has both low attention and response demand (e.g. for your information, FYI). Passive communication channels may also communicate to either individuals or groups. Communication may be facilitated by automated or personalised messages within the eLP. Table 4.2 categorises the codes and sub-themes analysed from the interview dataset within the classification category of the different communication channels to illustrate their practical uses in the eLP. The trainees (TN1-7) support for the 11 codes analysed is illustrated in table 4.2.

A large proportion of automated messaging will reduce time spent by the coordinator to assure effective communication, which is especially beneficial in low-resourced settings. However, the personal communication experienced by the trainees when arranging training sessions with trainers and trainer feedback on scans uploaded on the eLP will reconnect trainees with their trainers and the training programme. Integrating and optimising multiple communication channels within eLP context will reduce the impact of the isolation experienced by the trainees (Appendix E).

Table 4.2 **Multiple eLP communication channels supported by the sub-themes and codes analysed**

Category	Active	Passive
Individual	1. Trainee booking individual supervised training sessions with the trainer **(P)** TN3,4,7 2. Trainee scans feedback by the trainer uploaded via the eLP **(P)** TN1-7 3. Trainee inactivity reminders with guidance to access assistance for both trainee and supervisor **(A)** TN4 4. Build in quizzes at start and various progression levels during the training programme. Trainee must pass quiz in order to proceed to the next level **(A)** TN1,6	1. Scan portfolio individual dashboard showing current snapshot of scans completed/still required by trainee **(P)** TN1 2. On demand access to complete and detailed training programme information using an intuitive, easy to find visual layout design **(P)** TN1-7
Group	1. Regular countdown reminders before next course, scan portfolio submission and assessment deadlines **(A)** TN1,4 2. Trainee support group participation, including communication forums (peer to peer), arranging training sessions with "scanning buddies" and live chat rooms **(A)** TN3	1. Immediate post course introductory information guidance delivered within 24 hours after completion of the course **(A)** TN1-7 2. Training programme newsfeed on upcoming events (courses, logbook submissions, assessments, training sessions, etc.) **(P)** TN1-7 3. Posting availability and contact details of surrogate trainers (e.g. visiting fellows) **(P)** TN4

(A)= Automated, **(P)** = Personalised

4.5.4.2 Theme 3: Improved access

Improving the access to the correct eLP content for trainees and trainer instruction and/or feedback should have a positive impact on the time efficiency of trainees. However, the reverse is also true. Effective improvement of the time efficiency of trainees in finding the correct content will create their sense of having better access. The eLP's ability to re-enforce this loop is extremely important to assure its future success. Many of the trainees reported time constraints as their greatest barrier to successful credentialing.[15] The adaptability of the eLP end-user interface is critical to access task specific content and trainer feedback from any device at any location in the shortest

possible time interval within the context of local technical constraints, like variable internet access.

All trainees agreed that the eLP interface should be specifically adapted to function on desktop and mobile devises (m-learning) to render the tool accessible for performing the required task from any location, including the patient's bedside (TN2-7). "With my mobile phone I've adopted all new mobile technology" (TN6). Some trainees requested that the e-LP be extended to a down-loadable mobile application to expand its speed of use, accessibility and user-friendly interface to mobile users even further (TN5-7). "If someone can come up with an app it would even be better" (TN5). "I think an app should be amazing" (TN7).

4.5.4.2.1 Access to task specific content from any location

The eLP would need to store a blended bouquet of the entire content of the clinical ultrasound training programme within its repository (TN1-7). The content should be structured (TN1,2), "have a visual layout" (TN3,4) and include detailed sections on the following (Appendix E):

- Roadmap to credentialing (TN3,7);
- Trainee expectations (TN6);
- Learning outcomes (TN1,2);
- Logistics including an up-to-date news feed (TN4);
- Introductory course information (TN3,7);
- Complete core and background content for every module application included in the curriculum (TN1-7);
- Demonstration videos showing correct techniques to perform the various scans (TN1-7);
- Tips and tricks to deal with patients who prove difficult to scan (TN1,4,5,7);
- Adding scans to trainee's personal portfolio log (TN2,3);
- Pre-arrange personalised trainer training sessions (TN2,3);
- Upload and transfer scans from the ultrasound machine to eLP for off-site review by a trainer as an alternative route to receive feedback (TN1-7);
- Technical user instructions for the ultrasound machines (TN1-7);
- Formal competency assessment information (TN2,3,7).

Trainees suggested that the eLP should adapt to limited resource settings where some pre-selected content can be down-loadable for use in locations without internet access, including at certain training hospitals where many trainees will perform their scans for uploading on the eLP (TN7). The eLP end-user (trainee) interface should be uncluttered ("less is more" TN3,7) with prodigious use of drop windows to reveal the content when

trainees hover their cursors on the relevant button (TN2) to avoid unnecessary "clicking" (TN7). The toolbar should be "organised, clear, task specific and intuitive to enable fast, focused searches" and to guarantee high success rates (TN7).

The eLP should also provide archiving and security for the trainee personal scan portfolio log (TN2,5,7). The paperless portfolio log will save the trainee time by eliminating the need to maintain and physically transport a paper log as mentioned by TN1, "Not having to cart my portfolio log book everywhere". The dashboard that reflects the current status of portfolio log of the trainee should be located on the home page (post log-in) to personalise the interface thereby adding to a sense of belonging to the training experience (TN2-7).

4.5.4.2.2 Access to personalised trainer instruction

The time-consuming apprenticeship model where certified trainers provide real time feedback to trainees, while they scan patients in the hospital setting (personalised training), is still perceived as the gold standard in clinical ultrasound training.[13] "Personalised training is essential to create the confidence we require" (TN5). The individual personalised training sessions are currently arranged informally and, unfortunately, haphazardly between trainees and trainers, however, with a low conversion rate (TN4). TN4 remarked that "something always comes up and they are never available". All seven trainees suggested using an eLP on-line booking system to improve access to the preferred personalised training sessions (TN1-7). Trainees will be able to formally reserve their training sessions by selecting their availability, preferred location and trainer (trainers are linked to their work location). The trainer will confirm their availability by activating the session. TN7 described the meaning of having independent ownership to book a training session as "your name is now on it". The use of the asynchronous active individual communication channel will improve time efficiency by not intruding on any of the end-users' day-to-day activities. The eLP will also be able to provide a log of all communication threads between end-users (Appendix E).

4.5.4.2.3 Asynchronous trainer feedback

Previous studies have found that trainers were not always available to provide personal training to trainees due to their own heavy work burden or the non-availability of trainers at some of the hospitals where trainees are based.[9-12,14,15] The result is wasted training and trainer feedback opportunities that could have been utilised for the benefit of the trainees (TN1-7). To minimise the waste, trainees suggested an alternative route of asynchronous trainer feedback via the eLP where trainees capture, save and transfer

scan images (in the absence of trainers) from the ultrasound machine on to the eLP, when trainers are not available or "if all else fails" (TN7).

Trainers will be able to assess the submitted scan images off-site and asynchronously on the eLP at their own convenience. Trainers will also provide formal feedback and scanning improvement recommendations to the trainees via the eLP. The scan will be added to the portfolio log total of the trainee, only after trainer approval if all quality standards were met. The alternative route will prove to be time efficient for not wasting any scanning opportunities by always having an alternative access route to obtain feedback from the trainer. The direct effect will be less travel and more time saving for all end-users by not needing to attend as many personalised instruction sessions. However, the images upload and trainer feedback processes will need to be highly efficient for the alternative route to be successful.

The upload process of ultrasound images on to the eLP has to be simple, fast and adaptable and create high quality pictures to be a viable alternative. All uploaded images should be devoid of any patient identifying information. Automated cropping or encryption software that will de-identify scan images and capture sheets are options that should be considered. These aids will secure patient confidentiality and potential patient data breaches. Clear guidelines should inform trainees on the process for capturing the desired patient scan images onto the ultrasound machine (refer to visual benchmarking section). All trainees agreed that multiple options should be available to transfer captured images from the ultrasound machine to the eLP to allow for trainee diversities. However, trainees disagreed on the options they would personally use. Two preferred to use a flash storage devise (TN1,4) and five preferred using their personal mobile phone cameras to re-capture the saved images from the ultrasound machine screen and then transfer to the eLP (TN2,3,5-7). TN3 commented that "I would upload with my camera because it is so easy".

Unfortunately, pros and cons exist for both options. The flash storage device transfer option will assure no loss of image quality throughout the transfer process at the cost of less flexibility and time efficiency. Flash storage devise images can only be uploaded to the eLP when they are directly plugged into compatible ports and have simultaneous access to the eLP. This barrier may restrict trainees from uploading their images at the patient's bedside or place of work. Some trainees were disallowed to connect their personal flash storage devise to the ultrasound machines by trainers at certain hospitals for fear of virus infections, which eliminated their use at these locations (TN3).

The personal mobile phone camera option is much faster, can be used at any location including at the patient's bedside wherever the scan is captured. TN7 was of the conviction that the greatest benefit of using a personal mobile phone camera was, "I want to do real time uploading at the patient's bedside" because "I had million other things to do at home and I tend not to do my uploads then". Captured images can be stored on their mobile phone's drive or a Cloud drive during the transit process. TN6 was adamant that "I do not use flash storage devices anymore, everything is Cloud-based anyway". Using a custom designed application (app) can further enhance mobile upload of images. Uploading the patient details can then be streamlined by using the camera of a mobile phone as a bar code reader (TN7). "It would be awesome to do real time uploads by scanning the bar codes and taking the pictures with my own mobile phone camera" (TN7).

Five trainees agreed that they are willing to risk the possibility of capturing below standard ultrasound image quality with their personal mobile phone camera (reflections, glare, incorrect composition) and having their submissions declined by the trainer for having the benefits of the speed of upload and simplicity of transfer (TN2,3,5-7). "I think with today's smart phones you can take pretty good quality pictures" (TN7). However, some of them agreed that a practical guide to optimise personal mobile phone camera images should be added to the information section of the eLP (TN5-7). Both transit device options have the added function of storing the transition images as additional back up files in case they ever need to be retrieved. TN6 stated that "you should either provide the one or the other", which reflects most trainees opinion that the eLP should provide multiple options at every upload transit point so trainees can create their own most seamless route for image capturing, transfer and upload, depending on their own preferences, circumstances, skills and contexts.

The eLP trainee-upload interface (desk and mobile devises) must be clear, concise and intuitive (TN4) (Appendix E). Each of the application modules (such as, deep venous thrombosis ultrasound) should have its own separate heading in the toolbar (TN4). Each of the headings should open to a separate page using clearly marked stratified sections to guide the upload of ultrasound images to the correct location, implying for example separate upload sections for compressed and non-compressed femoral vein (TN2,4,7). Clear and visible instructions, including photo series with annotations and video guidance, should be visible and accessible near the upload location (TN3).

The trainer feedback quality differential, between the gold standard personal individual training sessions and the alternative asynchronous eLP feedback route, will need to be

minimal to assure future success. All trainees agreed that feedback from trainers must be comprehensive and prompted to closely reflect their learning outcomes. "The more detailed it is, the more you will probably learn from it" (TN6).

Five categories should be clearly stratified on the eLP feedback page on which the trainers will need to formally give feedback (TN1-7):

- Image quality; including composition, depth, gain or exposure, focus and time-gain compensation, artefact compensation as sub-stratification sections;
- Correct anatomy identified by clearly marking and annotating each structure;
- Correct pathology identified (if applicable) where pathology is clearly marked and annotated;
- Noting that the clinical indication(s) and objective(s) for performing the scan are correct;
- The scan findings affecting the patient clinical management are correct.

Trainees were critical on how they wished to receive their feedback. TN2 proposed that trainers should provide both objective (like a Likert scale) and subjective (via a comment box) feedback for each of the sub-stratified components on the feedback page.[34] TN2 also proposed using a forced feedback strategy via the comment box, if trainers rate any component below 60% on the Likert scale. However, trainers will be able to provide comments, even if they rate a component over 60% to minimise the impact of missed learning opportunities.

Three trainees advocated that trainers must focus their feedback on being positive and provide trainees with recommendations on how to improve their scanning practice (TN3,5,7). TN3 clearly stated that "feedback must focus on the aspects I need to improve on". TN5 reflected, "Their feedback should be used to improve our images". If the trainees meet the minimal requirements for all the of the feedback components, the trainers will accept the scan and it will be added to the personal log total of the trainee. If rejected, the scan will not be added and the trainee will need to repeat the scan. My view is that the trainers will need to be trained and monitor closely (quality assurance via the eLP) to assure their feedback adhere to the trainees' recommendations. Ironically, the starting point of my personal feedback, as programme director, to the trainers should also be positive and laden with practical recommendations to improve their feedback practice.

Trainees understood that improving their time efficiency might come at the cost of reducing their learning quality. All seven trainees agreed that adding annotations, by clearly marking the anatomical and pathological structures on the ultrasound image, is a

trade-off for using the asynchronous eLP feedback route (Figure 4.1). "It's a good thing we need to do" (TN3). Adding the annotations is essential for the offsite trainer to be able to assess the trainee's grasp of anatomy and pathology (one of the three core competencies). "Although it's a pain, using annotations will sort out your anatomy; it kind of forces you" (TN6). Adding the annotations to the image will come at the cost of reducing their time efficiency. However, trainees proposed many user-friendly options that may soften the time delay impact, namely:

- Add the annotations by using the ultrasound machine, prior to saving the image. The prepared and saved image with annotations can be transferred either via flash storage devise or captured with a personal mobile phone camera before uploading to the eLP (TN1,4);
- Annotations can be added during the image transit phase on PDF or JPEG files by using multiple software applications, before uploading to the eLP (TN2,3,5-7);
- Use mobile device applications to annotate images, e.g. Google Keep™ (TN6)
- Add a table that contains module application specific legends (see Figure 4.1, custom legends for the deep venous module application). The legends can be dragged from the table on to the ultrasound image after the image has been uploaded to the eLP (TN6).

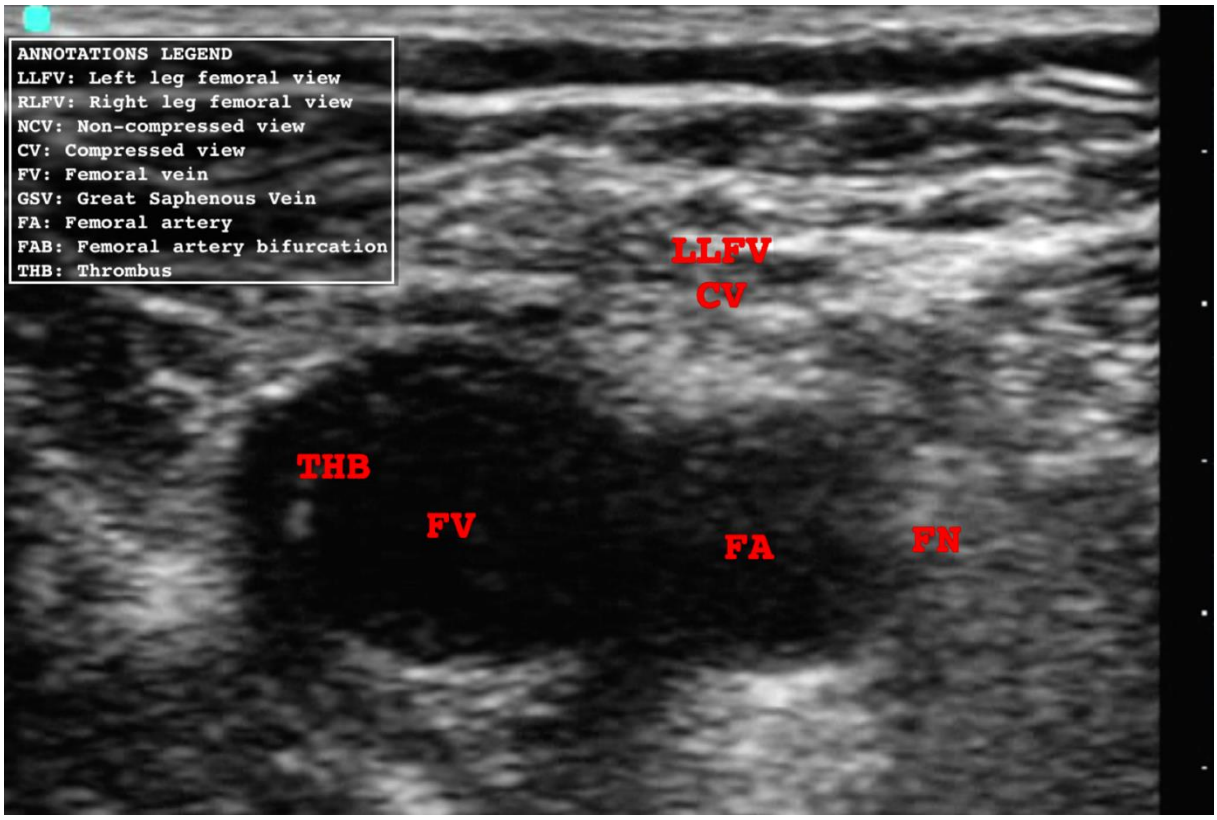

Figure 4.1 **Legend table for compressed left femoral view of deep venous thrombosis inside common femoral vein**

The trainees agreed that all annotation options should be added to the eLP, so any option can be used depending on the trainee's preference, skill and circumstances (TN1-7). They also recommended that clear guidance information should be added to the information section on how to use each of the options. Placing clear visual guidance, on how to perform specific tasks at strategic points, will elevate the eLP end-user experience resulting in access, time efficiency and learning delivery improvements.

4.5.4.3 Theme 4: Visual benchmarking

Training clinical ultrasound is a unique visual experience that requires the combination of hands-on and cognitive skills to recognise the anatomy and pathological processes. Acquisition and integration of these skills should lead to the correct interpretation of the acquired images. Finally, integrating the image findings with the relevant clinical data enhances the correct decision-making process during the rendition of patient care.[35] All trainees interviewed advocated the expansion of the visual learning experience throughout the eLP. "How positive and negative scan findings should look like" (TN4). The benchmarked ultrasound images should remove any doubt of the minimum quality level expected throughout the learning experience of the trainees.

4.5.4.3.1 Training programme information and guidance

Trainees proposed the minimal use of text to distract them from finding the information they require more effectively. They suggested we embed bold flow diagrams to illustrate most of the content, especially related to processes. For example, the road map to credentialing can be illustrated by using a diagram. Hovering with the cursor or clicking on a certain section of the diagram should provide the user with more detail. Comments like "Layout of the roadmap to credentialing should be clear so we know exactly what the process looks like" and "I like it visual" (TN3) have relevance. All "how-to" guidelines (such as, technical information on using the ultrasound machine, upload and transfer of images) should use photos with annotations to provide clear instructions for each phase of the process (TN4). The picture guide options are ideal for low internet bandwidth locations. However, short informative instructional video guides should also be offered in cases where the trainee has access to greater bandwidth connectivity. Providing more media options will cater to the specific needs and circumstances of the trainee.

4.5.4.3.2 Curriculum content

There was a near equal split between trainees preferring the eLP, hosting locally produced demonstration videos, to contextualise the curriculum content to their local setting (TN1,4,5,7) versus using existing videos on the Web as long as the content is approved by the local trainers (TN2,3,6). "I think it is a good idea if our local trainers can

vet videos we should use" (TN3). However, the trainees emphasised that all video content should be benchmarked against the competency standards expected from the trainees. Some trainees specifically requested the inclusion of locally produced videos that specifically demonstrate techniques to scan patients within an own context (e.g. unique pathology) and challenges (providing tips and tricks). "We want to see how they do it, so we know how to perform in the exam" (TN5). Many trainees called for these videos to be placed at multiple and strategic locations (content, upload and feedback sections) on the eLP (TN1,4,5,7). Trainees also advocated the maximum use of ultrasound pictures and videos throughout the entire eLP, as well as including regular interval on-line quizzes and recommended links for further background reading. "So you have pictures of everything" (TN4).

4.5.4.3.3 Image uploads

Trainees requested that ultrasound images with complete annotations be placed at multiple strategic locations (Appendix E). The quality and composition of the images and added annotations should be benchmarked at the standard expected from the trainees.

> *So people can benchmark by having a look before they upload their own images, so they can correct themselves* (TN4).
>
> *In my case, the biggest problem was that I did not know exactly what quality criteria to use for each scan; what the trainers wish to see* (TN7).

Annotations should identify the correct anatomical and pathological structures.

> *Guide images should be placed on the eLP that guides you to annotate your images correctly* (TN5).

Most importantly, the benchmarked images should be matched and placed at the specific stratified location where the trainees are expected to upload a similar image (e.g. deep venous thrombosis module application, compressed popliteal vein image) (TN4).

4.5.4.3.4 Trainee scan portfolio log dashboard

The trainee's personal dashboard (visual diagram showing the current status of the trainee's scan portfolio log) should be visible immediately when the trainees log in to their personal section (TN1-7) (Appendix E). Viewing a snapshot of their current progress may have many advantages:

- Act as a catalyst to motivate the trainee to continue submitting scans until their portfolio is complete.

- Act as a reminder (and prompt) if the trainee has not submitted any scans recently.

  There should be a visual alert if the trainee has not been logging their scans fast enough (TN4)
- Improve efficiency where trainees know exactly which type of scans are still outstanding.
- Sense of self accomplishment where the trainees can view their progress as a form of achievement for their efforts.

The advantages of the dashboard conspire to act as a passive motivational tool. However, in the case of a trainee not progressing, viewing their stagnation may have the opposite effect. It is imperative to have alerts, to both trainees and trainers, as part of the eLP's trainee monitoring system by using the passive individual communication channel in the case of trainee stagnation so as to intervene early and thereby minimise their negative experience.

4.5.5 Expectations of the eLP beyond credentialing

4.5.5.1 Theme 5: Restoring kindredness

The addition of the eLP, to create a blended learning approach, should re-connect the trainees to the training programme, their peers and trainers by creating an environment where they can make their own needs known. Many trainees insisted that their honesty should be trusted when they complete a written disclaimer to attest that they obtained the images legally for asynchronous trainer feedback. "Disclaimer should be sufficient" (TN5) (Appendix E). Its acceptance should act as the foundation of future bilateral trust between trainers and trainees. Re-connecting the trainees will restore their confidence and sense of belonging (TN2). This should motivate the trainees to learn and use clinical ultrasound in their daily clinical practice and also expand their confidence and sense of belonging beyond their clinical ultrasound training (only one of 23 core milestone competencies for an emergency medicine physician to acquire) to the rest of their emergency medicine residency programme training.[1]

4.5.5.2 Theme 6: Fostering pride

Many of the trainees showed pride in the unique context of their clinical ultrasound training programme. The training programme is conducted in a setting with a high emergency care workload (including a high ratio of seriously ill and injured patients).[32] Many of the high acuity patients present unique diseases profiles ranging from infectious diseases to malnourished patients and is reflective of the low-resourced setting they drain from. "I think our own context has such interesting pathology to scan" (TN7). Some trainees questioned the validity of externally created skill demonstration videos as an

accurate training guide for the diseases profile context of their own setting. "We should have our own local trainers demonstrating the correct scanning technique" (TN5).

Others recognised that their local diseases profile created its own scanning challenges, which render the need for locally produced demonstration training videos by local experts. "They've done this locally; they know how" (TN4). Two trainees requested that only the most senior trainers in the faculty, who they view as potential role models, should instruct on the demonstration videos to provide the quality benchmark expected from trainees (TN4,5). Some comments make reference to this, like "I know our trainer has done it this way"; "Then this is the way it should be done"; "This is the way I'm going to scan and have the confidence to do it" (TN5). The daily exposure of the trainees to seriously ill and injured patients result in a high ratio of patients with pathology to scan, which in turn contributes greatly towards the rate of skill acquisition by the trainee. The uniqueness of the patient profile of the training setting is enabling the trainees to develop expertise in certain diseases and trauma ultrasound exposures that are unique to the setting. Assimilating the eLP into a blended learning approach should reduce the factors contributing to sense of disconnection from the training programme reported initially by the trainees.

4.6 Discussion

4.6.1 Principal findings

There was no hierarchy amongst the themes that emerged from the theory. Instead, meaningful data patterns that have arisen from the trainees' experiences were arranged linearly into pre-, design of the eLP and beyond to provide a succinct answer to the research question.

Analysis of the trainees' negative experiences resulted in multilevel disengagement from the training programme. Interestingly, some trainees showed internal conflict between their own frustrations of having limited access to the trainers and understanding the trainers' severe work burden reality. However, out of necessity to complete the task of credentialing, trainees invented alternative pathways to overcome the challenges caused by their disconnection. They all used technology, each differently, to obtain their own meaning of learning with variable degrees of success reflecting the range of diversity amongst our trainees. Unfortunately, their individual reinvention marginalised them even more from the training programme, peers and trainers.

The theory that emerged from the participants' subjective reflections on their negative experiences enabled the design of an eLP to create inclusiveness by shifting the balance of power to the trainee. The learner-centred experience should result in a changing paradigm where trainees will control their own learning. Trainees should further benefit from the learner-centred experience the eLP offer by enabling them to control their own access thereby improving their learning delivery, restoring their learning enhancement and reconnecting them with their peers, faculty and content which should ring the start of their re-enfranchise process.

4.6.2 Relationship to other studies

The six study themes support most learning delivery and learning enhancement elements for e-learning. In turn, the elements and study themes are supported by the following well-known educational theories adapted to e-learning (Figure 4.2):

- Knowles Adult Learning theory[23,36-38]
- Flow-, Self-Determination- and Path-Goal Motivation theories[24-28]
- Learner Centred Learning theories[39,40].

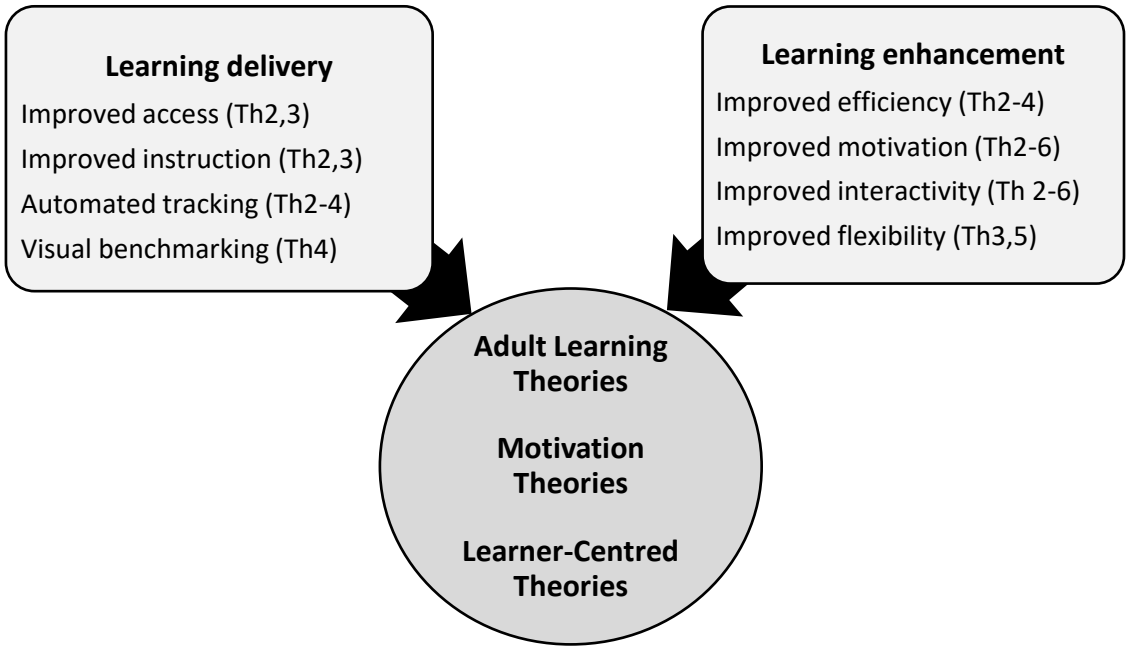

Figure 4.2 **Learning delivery and enhancement elements and study themes relationships with education theories adapted for e-learning**

Themes two (Th2) and three (Th3), together with two independent studies, support that improved access to information, content and instruction (personalised synchronous learning and asynchronous feedback) improves learning delivery.[16,17] Improved access

enables the trainee to find what is needed and when it is needed to include unplanned learning experiences, which is a common occurrence when scanning critically ill and injured patients in an emergency clinical setting.[17,41] Improved access supports the personalised nature of Adult Learning theory, more active engagement with content and patients of Motivation theories and enabling the trainee to control their own independent learning style (Learner Centred Learning theories).[22,23,31,42]

Three studies support our study themes 2-4 by recommending the use of a learning-management system that automates tracking and reporting of trainee activities and outcome assessments across an institution.[31,43,44] Displaying the trainee's scan portfolio log via a personalised dashboard reflects the current status of their scanning activities. Advocating the use of a highly visual display supports the visual learning experience of ultrasound learning. The principles of all three theories support automated tracking, including the use of direct and indirect feedback mechanisms, via versatile communication channels.

The novel visual benchmarking theme (Th4) of this study is unique to clinical ultrasound training and directly reflects two of the three major learning outcomes. What should the image look like (including the correct anatomy and pathology annotations) when the trainee is able to conjure up the image correctly? The so-called 'perfect image' should be placed at multiple and strategic locations across all platforms (eLP, mobile devise applications and ultrasound machines) to provide a quality benchmark to which all trainees and trainers can refer. All benchmarked images used should inform trainees actively (easy and on demand access) and passively (when they do not require access) throughout their learning experience period. All three theories support visual benchmarking indirectly.

The three theories support learning enhancement components more directly than learning delivery components. Improved learning efficiency, supported by study themes Th2-Th4, relates learning to specific needs, past experiences and applies learning practically to the desired learning objectives. Adult Learning theory and Learner Centred Learning theory directly supports a personalised learning experience while Motivation theories do so more indirectly.[23,31] Study themes Th2-Th6 directly refers to the end-user (trainee) interface design. A well-designed interface can motivate trainees to become more engaged with the e-learning content (Motivation theories), weaning their dependence from trainers (Learner Centred Learning theory and Adult Learning theory).[23] Interactive learning (between trainee and peers, trainer and content) shifts the paradigm from a passive teacher-centred model to an active, learner-centred model

(Learner Centred Learning theory and Adult Learning theory) resulting in a stronger learning stimulus (Motivation theories) with improved individual practice and reinforcement outcomes.[23]

Trainee self-motivation that re-enforces continuous practice is essential for trainees to eventually become competent in delivering clinical ultrasound skills in such challenging and stressful clinical settings. A United Kingdom study supports Th3 and Th5 where maximum trainee flexibility should be incorporated into the end-user design interface to accommodate diverse learning styles.[23] Our study advocates that multiple options should be included regarding content choice, management and delivery thereof. All three theories support improved outcomes when providing more trainee flexibility.

Applying e-learning to low-resourced settings include certain caveats. E-learning will only provide improved learner access and learning efficiency, if the new design is adequately aligned to educational and economic contexts of low-resourced settings; it has institutional readiness for e-learning adoption; and is supported by adequate infrastructural and human resources.[45] The current study addresses fully the first, partly the second and not the third criteria.

4.6.3 Strengths and weaknesses of the study

The small sample size (n = 7) of this study and the insider position of the main researcher may be perceived as weaknesses at first. However, the sample represented the full study population of all trainees who logged scans on the Cape Town training programme within the last two years, as clearly defined in the inclusion criteria. The in-depth two-step interview process, together with ample consultation and reflectivity between the first and second researchers until consensus of data mining and analyses saturation was reached, assured the necessary rigor to answer the original research question. The main researcher's insider position provided an expert overview. The insider positioning correlates with the over-arching action research study theme. The perspective and orientation of the main researcher towards the study is clearly stated throughout the manuscript.

This study benefited from the open-ended, inductive and exploratory thematic analysis approach to develop a theoretical model for designing an eLP within the context of the low-resourced setting of the trainees' with its unique challenges. The theoretical insights of this study correspond with related literature and known theories on e-learning. Novel theory also emerged that support the dominance of visual learning in the practice of clinical ultrasound training and its incorporation in the user-interface design.

4.6.4 Unanswered questions and future research

The limited focus of the study only informs on the initial eLP design to draft format. However, this study gives rise to many research questions. Once the draft is complete, further investigation into process evaluation of our eLP, by using its strengths and weakness and how the results are produced, will become necessary. At first, small peer review groups will need to internally validate the content of the eLP on how it is managed and distributed. This new academic scholarship activity should be considered as an additional scholarly requirement by the faculty. Subsequently, larger user-based groups will need to evaluate the usability of the eLP after the validation phase has been completed. It is expected that additional future research will be required on faculty adoption, their specific development needs and capacity-building during the eLP testing and roll out phases.

4.7 Conclusion

The competency-based curriculum of clinical ultrasound training is ideally suited for e-learning. Personalised instruction is still deemed as the gold standard, although it is very time consuming to bear in a clinical environment where time availability will become even scarcer in the future. The results of this study, its relationship to other studies and support by existing education theories, advocate using a blended learning approach where e-learning should be offered complementary to personalised instruction and not a substitute. However, the success of the e-learning component measured against learner-centred experience, adult learning theory, motivation theories and eventually credentialing outcome, will depend on how effectively the eLP design (especially the user-interface) can integrate with context specific requirements of the trainees (the study themes).

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Chapter 5

E-learning platform to improve learning delivery

5.1 Article 4: Title

Development of an e-learning platform to improve learning delivery in a low-resourced clinical ultrasound training setting using a participatory action research approach

5.2 Abstract

Background/Objective: Some clinical ultrasound training programmes provide suboptimal training resulting in credentialing failure. To address this failing in our low-resourced setting, the objective of this study was to custom design and construct an e-learning platform (eLP), using a participatory action research approach. Collaborations between trainees, e-learning developers and researchers set out to improve the trainees' access to learning delivery and eventually enhancement with the aim to alleviate the problem of Cape Town's CUS training programme's low credentialing success rate.

Methodology: The participatory action research approach employed a mixed methodology to collect, manage and analyse data for each of Susman and Evered's cycle of enquiry steps consisting of diagnosis, action planning, intervention, evaluation and reflection. The integration of instrumental and focal theories closed the practice-research gap by adding the necessary rigor to the study.

Results: The diagnosis step revealed that poor credentialing performance was due to a learning delivery block that impaired the academic engagement of the trainees to learning. An e-learning platform was designed and constructed (intervention) to consolidate the current training capacity and provide alternative access pathways to learning delivery (action planning). The e-learning platform was designed around Learner-centred, Adult learning and Motivational pedagogical paradigms. Evaluation of the e-learning platform intervention identified context-specific resource savings, that all study participant groups accepted the new reality of incorporating e-learning as part of

a blended learning approach and learning access of trainees improved. Future research should focus on validating the usability, learning delivery and enhancement of the draft e-learning platform, initially by means of small peer groups followed by more comprehensive evaluation via larger user-based groups (reflection).

Conclusion: Collaboration led to real practical and social change by creating a custom designed e-learning platform that changed the way clinical ultrasound trainees learn in our low-resourced context. Early inclusion of the trainees as study participants lead to their early adoption of the e-learning platform's ability to first unblock their learning delivery, then restore their academic engagement, and eventually their learning enhancement, which could reflect in improved credentialing success rates.

5.3 Introduction

Clinical ultrasound (ultrasound performed by clinicians at the patient's bedside) is a core skill for providing effective emergency medicine practice.[1-7] Operator competency, backed by rigorous credentialing standards, is essential to reduce medical errors and assure patient safety.[8] Some emergency medicine residency training programmes fail to provide efficient clinical ultrasound training to their residents resulting in low credentialing success rates.[9-12] One reason is the multiple scans trainees are required to perform under direct trainer supervision in busy emergency departments to become skill competent.[13] Increasing clinical care provision and medical education demands on both the trainees and trainers create severe conflicts with the current time consuming clinical ultrasound training model. Cape Town (South Africa) reported a 19.7% credentialing success rate, the lowest of seven peer training programme outcomes.[14] This study focused on finding a new plan (intervention) to improve Cape Town's future clinical ultrasound credentialing success rate within its low-resourced context.

An action research approach seamlessly combines the practical and research paradigms into a single methodology.[15] Unlike other designs, the research focus shifts to the collaborative roles between the researchers and clients of the organisation (in our case, clinical ultrasound trainees) by participating in the research itself, while improving a "real world" problem.[16] Our study followed the participatory action research approach where the researchers', trainees' and e-learning developers' interactions were mutual and collaborative to improve practice (credentialing outcome) through the application of the personal wisdom of the participants within a particular context.[17,18] A landmark study by Davison et al. (2012) advocated the use of theories (focal and instrumental) to enhance the cyclical action research process by improving both practical outcomes

and scholarly benefits.[19] The iterative and cyclical participatory action research process of Susman and Evered (Figure 5.1) was followed to solve the problem of the clinical ultrasound training programme's low credentialing success by providing guidelines for the design and creation of an e-learning platform (eLP, intervention) to provide a blended learning strategy to our trainees.[20]

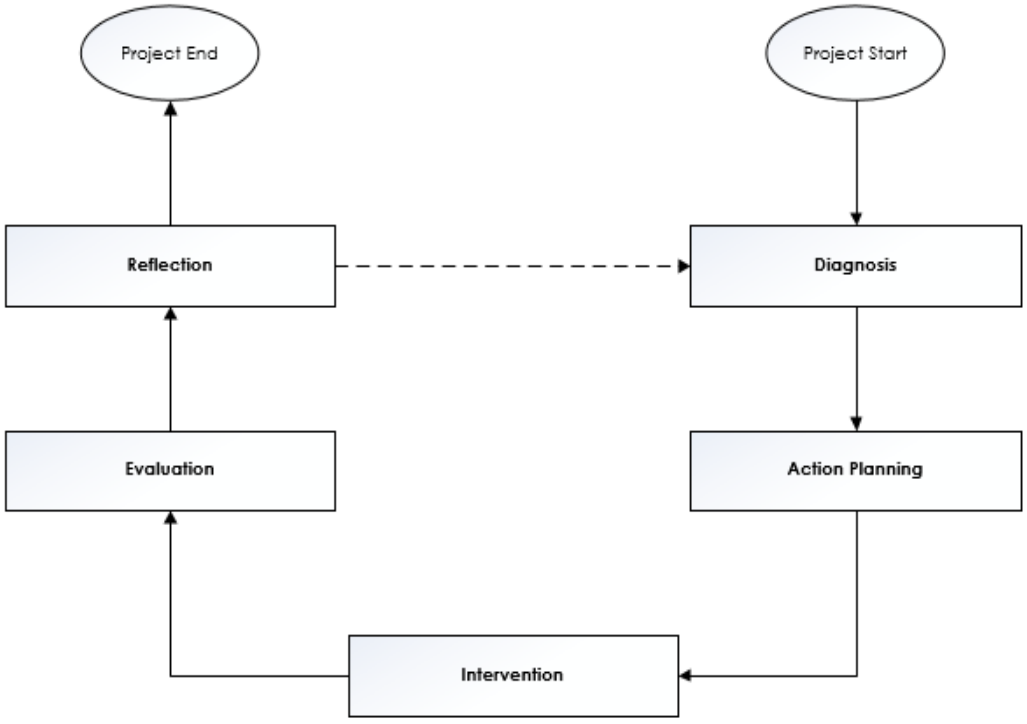

Figure 5.1 Susman and Evered's participatory action research cycles of reflective enquiry

Learning delivery refers to the accessibility of information, curriculum content, personalised instruction and accountability for learners.[21,22] Learning enhancement refers to learners making links to specific needs by practically applying new learning to past experiences thus making the experience deeply personal and effective.[23] This efficiency is more likely to translate into improved motivation and performance.[24] Current evidence supports increased learner satisfaction, product utility and cost effectiveness when using e-learning.[22,23,25] E-learning (also known as Web-based learning, online learning and Internet-based learning) improves learner knowledge and performance by using Internet technology to deliver multiple and diverse learning modalities.[21,22,26] E-learning can significantly decrease costs by as much as 50%, when compared to traditional instructor centred models, thanks to savings on instructor training time, travel costs, institutional infrastructure, and printing and distribution of educational materials.[23,25] Such cost savings would benefit low-resourced settings like the one in the context of this study.

Clinical ultrasound's competency-based curricula that specifically focus on learning outcomes are ideally suited for e-learning.[27] A Canadian study reported improved skills proficiency of certain ultrasound-guided procedures after e-learning was integrated into their existing training programme.[28] Given the advantages reported, limited evidence exists for adapting and integrating e-learning to the context of training doctors in clinical ultrasound, while they render emergency patient care in a high stress environment, especially in low-resourced settings where it is most needed. The purpose of this participatory action research project was to engage, empower, collaborate, and enable the acquisition of knowledge by creating social change of all study participants during the design and construction of an e-learning platform (eLP).[29]

The research objectives were to custom design and construct an e-learning platform (eLP) in our low-resourced setting by using a participatory action research approach by means of collaborations with trainees, e-learning developers and researchers to improve access to learning delivery and eventually learning enhancement of the trainees, and to alleviate the problem of the low credentialing success rate of Cape Town's clinical ultrasound training programme.

5.4 Methodology

The participatory action research approach followed the Susman and Evered's cycle of enquiry steps (Figure 5.1).[17,18,20] All study participants (researchers, trainees and e-learning developers) actively collaborated as equals by custom designing an eLP with the view to improve the clinical ultrasound credentialing outcomes of trainees within a low-resourced context. Participants worked within an interpretivist paradigm, and relativist ontological and subjectivist epistemology perspectives, which align well with a participatory action research approach. The first author had an insider and stakeholder perspective and relationship with the other study participants (certified emergency physician, clinical ultrasound trainer and faculty and director of the clinical ultrasound training programme). The first author conducted the data collection and performed the data analysis. The second author assisted with the data analysis.

5.4.1 Study context

The study was conducted in the emergency departments of Cape Town's public hospitals (low-resourced setting) that hosted emergency medicine residents from Stellenbosch University and University of Cape Town specialist training programme. These hospitals have severely overcrowded emergency departments with a high patient

turnover and low doctor-to-patient ratio.[30] Most patients present to the emergency departments with serious illnesses and injuries, which reflects the high occurrence of violence and communicable diseases in the community.[31] Together these factors compound the resources mismatch leaving less time available for effective clinical ultrasound training. Trainees are required to complete 65 trainer approved proctored scans in their personal portfolio log that are all conducted within these busy emergency departments. They have a two-year time limit to complete their scan requirements, which starts after attendance of the introductory ultrasound course, to be eligible to challenge their final competency assessment.[32] Our training programme reported a 19.7% credentialing success rate (certified trainees who passed the final competency assessment) from 2009 inception to 2015.[14] The Susman and Evered participatory action research approach was applied to solve the real world problem of the poor credentialing success rates of the trainees.

5.4.2 Data collection and sampling

Data collection, sampling, management and analysis followed Susman and Evered cycle's steps of enquiry as presented in Table 5.1 and Figure 5.1.

5.4.2.1 Individual Interviews

In-depth, individual interviews were conducted with all seven registered emergency medicine residents (clinical ultrasound trainees) whom had actively partaken in the training programme activities within the last two years (April 2014 to April 2016). The activities include the attendance of an accredited introductory CUS course and any logged scans recorded in their personal portfolio log. In-depth individual interviews were an appropriate choice considering the small study population and the logistical difficulty to arrange the trainees into focus groups due to their demanding work schedules. The interviews were conducted in two phases.

The first phase was exploratory considering the context specific nature of the study and how little was known on the topic. One randomly selected study participant (trainee) was individually interviewed by asking open-ended exploratory questions about the trainees, trainers, setting, logistics and eLP design roles in improving the future credentialing success (Appendix C). The primary researcher conducted the interview in November 2015 at the trainee's Cape Town based hospital. First level analysis was completed up to the point of establishing provisional themes. The purpose of the exploratory interview was to use the codes and themes to refine the semi-structured questions for the second phase interviews that focused on the eLP design components,

namely communication improvement, educational content, end-user interface, ultrasound images upload and transfer, trainer feedback, add-ons and quality assurance (Appendix D).

The second phase interviews included all seven active trainees located within Cape Town's public hospitals domain (sample matches the study population). All interviews were conducted between November 2015 and April 2016 at the base hospitals of the study participants. The interviews lasted 31 minutes on average.

5.4.2.2 Electronic mail survey

Trainees, who attended the introductory course of the Cape Town training centre between 1 June 2009 and 30 June 2013, were eligible to partake in the survey. Two hundred and eighteen trainees were invited by e-mail to complete an online questionnaire conducted in October 2013 to investigate the barriers that caused the low credentialing success. All trainees who responded to the survey were followed until the end of the required two year training period in 2015 to stratify whether they successfully credentialed as clinical ultrasound providers (credentialed group) or not (non-credentialed group) to reduce the impact of responder bias in the analysis.

5.4.2.3 Systematic review

The PRISMA-P statement (2015) was followed to source and critically analyse relevant data for this study.[33] Searching databases and other sources identified the appropriate records. Duplicate records were removed after a systematic screening process. Remaining records were assessed and included, if eligible. Non-eligible records were excluded with reasons. All remaining eligible studies were included for qualitative and quantitative synthesis via critical analysis. Studies were included for analysis only after they met both inclusion criteria:

- Studies that reported on the clinical ultrasound training of physicians (non-radiologists), irrespective which speciality they represented.
- Studies where the training programme's credentialing or certification outcome was reported specifically.

Table 5.1 **Data collection, sampling and analyses for each of Susman and Evered cycle's steps of enquiry**

Susman and Evered cycle(S)	Data collection	Sampling methods	Analyses
Problem diagnosis	Individual interviews	Emergency medicine residents who entered the CUS training programme by attending an accredited introductory CUS course and actively logged any of the required 65 ultrasound scan investigations to their personalised portfolio within the last two years (2014 – 2016) were eligible to partake in the study (n = 7)	Inductive thematic qualitative analysis
	Individual interviews	Same as above (n = 7)	Deductive qualitative analysis informed by focal and instrumental theories
	Electronic mail survey	Cape Town introductory ultrasound courses attendees between 1 June 2009 and 30 June 2013 who responded by completing a questionnaire (n = 86)	Descriptive statistics as informed by Check and Connect focal theory
	Systematic review (Prisma-P statement)	Studies were included for analysis if they reported on the CUS training of physicians (irrespective of speciality represented) and where training programme's credentialing or certification outcome was reported specifically	Critical analysis as informed by Check and Connect focal theory
Action planning	Individual interviews	Same as above (n = 7)	Inductive thematic qualitative analysis
	Individual interviews	Same as above (n = 7)	Deductive qualitative analysis informed by focal and instrumental theories
	Researcher notes from group meetings	Researchers and e-learning developers (n = 4)	Deductive qualitative analysis informed by focal and instrumental theories
Intervention	Individual interviews	Same as above (n = 7)	Inductive thematic qualitative analysis
	Individual interviews	Same as above (n = 7)	Deductive qualitative analysis informed by focal and instrumental theories
	Researcher notes from group meetings	Same as above (n = 4)	Deductive qualitative analysis informed by focal and instrumental theories
Evaluation	Individual interviews	Same as above (n = 7)	Deductive qualitative analysis informed by focal and instrumental theories
	Researcher notes from group meetings	Same as above (n = 4)	Deductive qualitative analysis informed by focal and instrumental theories
Reflection	Reflective journal	First and second researchers (n = 2)	Deductive qualitative analysis informed by focal and instrumental theories

5.4.2.4 Group meetings

Five group meetings were held from July 2013 to May 2016 at the e-learning developer's offices lasting 79 minutes on average. All meetings were audio recorded and included the first author and three e-learning developers. Meetings followed a strict practical agenda, different for each meeting, depending on the eLP development stage. Although invited none of the clinical ultrasound trainees managed to attend any of the five meetings due to conflict with their busy clinical schedules. The first author acted as the mediator between the trainees and e-learning developer to assure the link between the participant's needs and requirements were kept intact by including the trainees' design proposals in the construction of the eLP.

5.4.3 Data management and ethics

The first author explained the individual interview and group meetings procedures and guaranteed participant confidentiality at the start of all activities. All participants, including their responses, were anonymised within all data sets. Trainees and e-learning developers provided written formal informed consent to the audio recording of their interviews and meetings. All seven interviewed trainees received a verbatim transcript of the contents of their interview for member checking. Of the seven interviewees, only one suggested minor changes that were included prior to data analysis.

The trainees' participation in the survey implied consent. Non-responders were reminded at 1-week intervals until they responded or the submission deadline expired after a one month period. The survey collected no personal or identifying information to protect participant confidentiality. The online survey platform anonymised all responses before converting the data into an electronic spreadsheet (Microsoft Excel®, Microsoft Corporation, Redmond, WA). The electronic spreadsheet was password protected to ensure the integrity of the data.

Retrospective studies that met the inclusion criteria for the systematic review were appraised according to Gilbert and Lowenstein criteria.[34] No studies were excluded on the risk of bias. The first author kept a reflective journal from the onset to completion of the study project.

The Health Research Ethics Committee at Stellenbosch University approved the study (Ref: N13/04/056).

5.4.4 Analyses

All audio-recorded individual interviews and group meetings were transcribed verbatim. Line-by-line data analysis was conducted manually directly from the audio transcripts.

5.4.4.1 Inductive analysis using the thematic approach

During the intervention step of Susman and Evered's cycle, the themes identified by inductive analysis that pertained to the needs of the trainees, were exclusively used to create eLP design proposals. Group meetings with the e-learning developer transformed these design proposals to the construction of a first draft eLP.

5.4.4.2 Descriptive statistics survey analysis

Descriptive statistics were used to depict the survey's variables. Perceived barriers to credentialing were ranked to support the problem diagnosis step of Susman and Evered's cycle. The most important barrier for each participant received a value of '1', the second most important barrier a value of '2' and so forth until the least important barrier received a value of '7'. A mean ranking score was calculated for every barrier (denominator used was the number of participants that ranked that specific barrier); the top ranked barrier would therefore achieve the lowest mean score.

5.4.4.3 Critical analysis of systematic review

The primary outcome measure was to critically analyse the credentialing outcome of the Cape Town training centre in relation to the other studies identified in the systematic review. Simple percentage measures, calculated from trainees who entered and eventually successfully completed their training programmes, were used. The secondary outcome measure was to critically analyse patterns that successful and lesser successful training programmes had in common with the Cape Town clinical ultrasound training programme to enable the problem diagnosis step from a logistical perspective.

5.4.4.4 Deductive analysis using instrumental and focal theories

Both instrumental and focal theories were used to guide the deductive analysis process for each of Susman and Evered cycle's steps. The inductive analysis results appraised the most relevant and justified instrumental and focal theories to be used for each step. Instrumental theories usually inform activities to achieve the practical needs of the participatory action research project.[19,20] In turn, focal theories specifically guide the intervention (eLP design and construction in our study) with the aim to solve the problem identified in Susman and Evered's diagnosis step and simultaneously accomplish the research needs of the study.[19] If deployed efficiently together, they potentially close the practice-research gap that often occur between the practical and research paradigms

and has the potential to threaten the validity of participatory action research projects.[19] Figure 5.2 illustrates how the study integrated instrumental and focal theories into Susman and Evered cycle's steps to improve the study's rigor.

5.5 Results and discussion

The iterative cycle steps of Susman and Evered were used to report the results (Figure 5.1). Figure 5.2 illustrates how the focal and instrumental theories were integrated with Susman and Evered's steps for the purpose of improving practical outcomes and scholarly benefits of the study.[19] Instrumental theories are practical and close the gap between the practical and research agendas by acting as a mediator to explain common phenomena that affect both. The Check and Connect (C&C) instrumental theory provided an immediate and solid framework to accurately diagnose the problems that caused the low credentialing success of our clinical ultrasound training programme. The same instrumental theory was also used to evaluate if the diagnosis problem was effectively solved by the changes made. The e-Learning Scorecard (eLSC) usually functions as an evaluation instrument. For the instrument to be effective, its components should also be included during the action planning step. Instrumental theories verify and then compliment focal theories. Focal theories should emerge during the problem diagnosis step, as the Learner-Centred Design Theory (LCD) did in this study. Adult Learning (ALT) and Flow Motivational (FMs) focal theories emerged during the action planning step. Together the three focal theories specifically guided the eLP design intervention process by informing the relevant steps of S&E.

The same three focal theories were used to evaluate if the eLP design intervention delivered the actual change that was initially expected. All instrumental and focal theories used were thoroughly reflected upon against their outcomes and appropriateness during the final Susman and Evered step (Figure 5.2).[19]

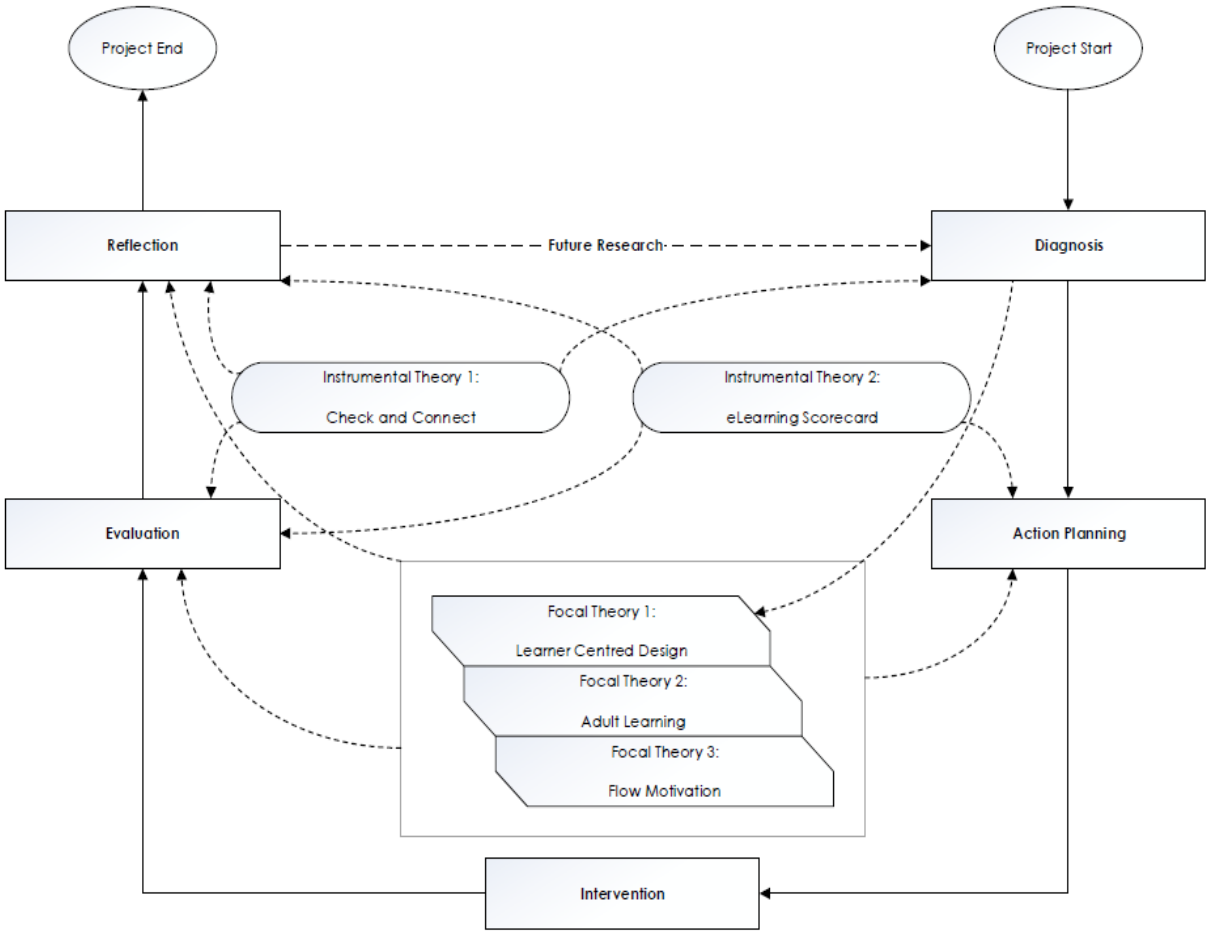

Figure 5.2 **Applying instrumental and focal theories to Susman and Evered's participatory action research cycle(s)**

5.5.1 Diagnosis

A Cape Town study of the same sample reported disenfranchised trainees that experienced disconnection from the clinical ultrasound training programme.[35] Our study employed the Check and Connect instrumental theory to provide us with an in depth diagnosis of our trainees disengagement (Figure 2).[36,37] Alternative instrumental theories that measure student engagement use questionnaires, aimed at large school group samples with varying degrees of validity.[38] We selected the Check and Connect theory for its flexibility to adapt to after school settings and diagnose student disengagement in small samples by using interviews instead.[36-38] Furthermore, the Check and Connect instrumental theory provides an in-depth analysis of academic, behavioural, cognitive and affective student disengagement and the inter-relationships between the different categories providing a much richer diagnosis (Figure 5.3).[36,37] Academic and behavioural categories are observable engagement markers mostly affected by curriculum content and learning delivery. Cognitive and affective categories are internal engagement markers. Parents, upbringing, friends and partners mostly affect the trainees' cognitive

engagement. In contrast, teachers, trainers and lecturers mostly influence affective engagement.[36,37]

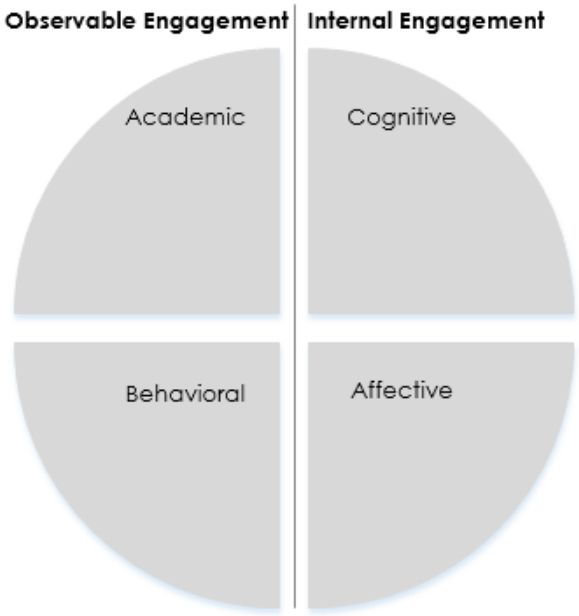

Figure 5.3 Appleton's Check and Connect instrumental theory categories (2006)

5.5.1.1 Academic engagement

Academic engagement mirrors the performance output of the clinical ultrasound trainees. Only one in five of the trainees (19.7%) who entered Cape Town's training programme from 2009 inception to 2015 successfully credentialed.[14] The majority of trainees who failed to credential (80.3%) did not complete their 65 required scans to gain the necessary skill experience to qualify for the competency assessment. All scans performed require trainer feedback and quality verification (direct supervision or from archived images) to qualify. The scans must be completed within two years after attending a College of Emergency Medicine of South Africa accredited introductory course. The high dropout rate measured was secondary to low task completion. Analysing the root causes for the poor academic engagement will be critical to plan for an effective action intervention to solve the problem of low credentialing.

5.5.1.2 Behavioural engagement

The trainees' behavioural reaction to the training programme activities is reflected by their behavioural engagement. Some of the trainees reacted positively to the academic disengagement experienced by "emerging themselves in self-study to fill the void" (Trainee 1: TN1) and "doing things on their own" (TN1) to improvise an alternative pathway to reconnect to learning. Other trainees had negative experiences at first by

being "terrified" (TN3) of having limited access to both learning delivery and enhancement. Eventually the trainee overcame the sense of fear by partnering with a trainee colleague ("scanning buddy" TN3) to perform self-training scans on patients together. Overall, all the trainees' interviewed behaved positively and resourcefully towards the learning delivery block and the consequential academic disengagement experienced by inventing creative alternative pathways to reconnect with their learning. However, we suspect that the large majority (80.3%) who failed to credential over the years were unsuccessful to re-invent themselves to compensate for the learning delivery block and disengagement experienced. The action plan (intervention) will need to reconnect the majority of trainees to learning, especially those who were not as inventive.

5.5.1.3 Cognitive engagement

The trainees' cognitive engagement is the perceived relevance of learning clinical ultrasound to their future emergency medicine clinical practice. Emergency medicine is a highly stressful medical specialty where fast and accurate diagnosis directly improves the patient's outcome when dealing with severely ill and injured patients. Clinical ultrasound is a core skill that provides the fast and accurate assessment that's an absolutely necessity in modern clinical practice. Furthermore, Clinical ultrasound creates a unique visual and fun experience where practicing clinicians, trainees, trainers and patients can actually see the anatomy and pathology within seconds (in real time) without creating any discomfort or potential side effects to patients. All our trainees interviewed and surveyed (including the non-credentialed group) recognised the relevance of clinical ultrasound and understood the value of its learning and the success it would bring to their future clinical practice.[35,39] Many trainees who dropped out and failed to credential were ardent to resume their training whenever better access to learning delivery can be assured.(39)

5.5.1.4 Affective engagement

Trainees identified with their own low-resourced setting's challenges, especially the unique patient pathology profile they were challenged with on a daily basis. Many trainers were perceived as role models due to their high clinical ultrasound skill set in scanning unique and different patient pathology profiles (e.g. severely injured patients, human immunodeficiency virus and tuberculosis scanning). "We should have our own local trainers demonstrating the correct scanning technique" (TN5).

Some trainees even showed pride in the sense of belonging to such a unique training programme.

> *I know our trainer has done it this way. Then this is the way it should be done. This is the way I'm going to scan and have the confidence to do it (TN5).*

Ironically the same "role model" trainers were contributing to the problem by not being accessible for personal supervised training sessions. TN4 remarked: "something always comes up and they are never available". However many trainees understood the trainers' reality of a crippling workload that creates less training opportunities for them. "It comes down to that no trainer has any time to train me because everyone is just so busy" (TN1). Remarkably the trainees' affective engagement was still intact considering the learning delivery block they were exposed to.

5.5.1.5 Root causes

A survey that was conducted amongst 213 trainees who entered the Cape Town's clinical ultrasound training programme from inception in 2009 to 2013 returned a response of 90 (41.3%) completed surveys. The highest ranked barriers that lead to their academic disengagement from a trainee perspective were, in order of importance[39]:

- Limited time available in their busy schedules to train clinical ultrasound
- Limited access to trainer feedback
- Technical difficulty in saving the scan images for feedback.

A systematic review and qualitative analysis of Cape Town's learning delivery successes and failures, in relation to six peer international clinical ultrasound training programmes, reported logistic failure similarities amongst the programmes that performed poorly. Those programmes (including Cape Town's) that trained over long distances, used multiple training sites and allocated fewer resources towards their training, had worse outcomes than their peers.[14] All these logistic failures conspired to reduce learning delivery to Cape Town's trainees, which resulted in their academic disengagement. We expected that unblocking the trainees' learning delivery would restore their learning enhancement, immediately improving their behaviour, cognitive and affective and eventually their academic engagements. In essence, to effectively unblock the trainees' learning delivery, the focus of learning should shift from the trainers to the trainees, which supported the emergence of Learner-Centred Design (LCD) focal theory. Learner-Centred Design theory provided the necessary guidance for the eLP design and construction (Figure 5.2) and also informed on which supplementary focal theories to use during the action planning step.[40,41]

5.5.2 Action planning

Given the problems related to the learning delivery block of our clinical ultrasound trainees and the restrictions posed by our low-resourced setting, actions were required that improved their access, while minimally exhausting our scarce resources. The most viable and cost effective action plan was to design, construct and add an eLP to the current training programme offering to provide the trainees with a blended learning approach. We decided to frame our solution by using both a short and long-term action plan.

The short-term action plan was to use the eLP to optimise and consolidate the training capacity we already had. The immediate objective was to create access to task specific content for the trainees via their desktop and mobile device from any location. The eLP toolbar should be "organised, clear, task specific and intuitive to enable fast and focused searches" (TN7). The content should include their learning outcomes, expectations, and training programme content and information. The next short-term action plan phase was to improve the trainees' access to personalised trainer instruction (gold standard) by creating an online booking system, where trainees can reserve their personalised training sessions with the trainer of their choice using the eLP. Trainees would request a training session by selecting their time availability, location and trainer (trainers are linked to their work locations). The trainers would then confirm their own availability to activate the session. TN7 described the meaning of having independent ownership to book a training session as "your name is now on it".

The long-term action plan was to create an alternative pathway for trainees to access asynchronous trainer feedback of their submitted scans through the eLP. The trainers' severe workload contributes to the low conversion rate of pre-arranged personalised training sessions. Trainees will capture, save and transfer scan images (in the absence of trainers) from the ultrasound machine to the eLP. The trainers will be able to access the submitted images and provide asynchronous feedback at their own convenience. The feedback should be objective (Likert scale), subjective (comment boxes), detailed (image quality anatomy, pathology, clinical indication/s) if the scan correctly affected the patient's clinical management, structured (stratified) and positive by focusing on how to improve the trainees' skills.[42] If the trainees scanned images meet the minimal quality requirements, the scan should be added to their personal portfolio log total that will reflect on their personal dashboard. The alternative asynchronous feedback route should enlighten the task completion (academic disengagement) of logging the

required 65 scans to their personal portfolio so that they are able to qualify for the final competency assessment within the two-year training period.

This study used the e-Learning Scorecard (eLSC) instrumental theory, in addition to the Check and Connect, to facilitate the eLP design and construction processes (Figure 5.2).[43] The e-Learning Scorecard is a measurement instrument for evaluating e-learning projects based on the well-known Balanced Scorecard theory.[43,44] However, to enhance the eLP's proficiency, the evaluation components of the e-Learning Scorecard theory should be integrated during the action planning phase. The instrument is flexible and adaptable by allowing researchers to choose their own four perspectives of measurement and analysis most suitable to their e-learning project. We chose:

- Resource savings to fit with our low-resourced setting instead of finance;
- Trainee acceptance instead of stakeholders acceptance;
- Improved access to learning delivery instead of increasing productivity;
- Innovations and knowledge.

This study used three focal theories to guide Susman and Evered cycle's action planning by designing and constructing a fit-for-purpose eLP (Figure 5.2). Learner-Centred Design theory principles concentrate on improving the quality of e-learning by meeting the diverse and unique needs of trainees, while maintaining rigorous expectations and quality content (Table 5.2).[40,41] Integrating Adult Learning theory principles to our eLP design will maximise the engagement and motivation of our trainees by creating more meaningful learning experiences as adult learners (Table 5.2).[45-47]

Applying the Flow Motivational Theory to the eLP design will improve our trainees' intrinsic motivation and consequently their performance, creating a sense of losing themselves in their learning experience (Table 5.2). Optimising the trainees' flow will enable them to fully and voluntarily engage with their training, control the pace of learning to their needs, preferences and context challenges. When trainees are able to lose themselves in learning, they can effortlessly master skills and overcome challenges to combat the academic disengagement caused by the learning delivery block they currently experience.[48]

Based on the diagnosis of the academic disengagement of our trainees caused by learning delivery failure, the application of specifically selected instrumental and focal theories will add much needed rigor and drive to the design process of eLP to alleviate the access block they experienced.

Table 5.2: Principles of focal theories applied to action planning and evaluation

Focal theories	Principles
Learner-Centred Design Theory (40, 41)	Applying learning of the trainees to their real world context; Constructing the trainees' new learning with previous experiences and knowledge; Collaboration between trainees to solve problems; Communication (including feedback) so trainees can make sense of their learning.
Adult Learning Theory (45-47)	Self-concept by creating minimum instructions and maximum trainee autonomy; Varied instructional design models to accommodate different experience levels and backgrounds; Using social media and on-line collaboration tools to tie learning to social development; Application of the subject matter to solve the trainees real world problems; Creating motivation for the trainees by providing valid reasons behind educational activities; Involving trainees in the design and development of the eLP; Experience should be at the root of all e-learning tasks and activities; Tying in real life applications and benefits to the e-learning tasks and activities; Providing trainees with enough time to absorb information rather than memorise it.
Flow Motivational Theory (48)	Specifying the trainees tasks clearly; Providing feedback to trainees; Balancing their challenges with their abilities and time allocations; Providing trainee control; Providing consistency.

5.5.3 Intervention

Stakeholders, researchers, trainees and e-learning developers endorsed the implementation of the eLP tool to improve the trainees' learning delivery within our low-resourced setting context. An eLP was designed and constructed up to the first draft stage guided by using the six main themes identified during the thematic analysis process, namely disenfranchised trainees, versatile communication channels, improved access to content and trainer instruction (synchronous and asynchronous), visual benchmarking of the quality images expected from trainees, restoring the trainees kindrednesss and fostering pride in the uniqueness of the learning experience offered.[35]

5.5.4 Evaluation

The evaluation step concentrated on the changes experienced by all participant groups (researchers, stakeholders and trainees) following the draft eLP intervention by applying the same instrumental and focal theories that emerged during the earlier steps of Susman and Evered. All trainees interviewed, immediately indicated the eLP's benefits of providing instant and on-demand access to task-specific content through the new multiple communication channels, providing them control over their own learning. The

trainees reported that they were initially sceptical of the eLP's ability to provide an alternative route for asynchronous trainer feedback on their scans. At first, trainees reported clinging on to their optimistic expectations that the eLP would increase their personalised trainer instruction sessions and therefore solve the access challenges. However, as they shared their personal endeavours, enhanced by their technology prowess, they reported of becoming more convinced that creating an alternative route for asynchronous trainer feedback on their submitted scan images via the eLP would provide a viable additional pathway to complete the required 65 scans within the two-year time limit. Trainees reported that they were confident the eLP tool's autonomous learner-centred experience would fully integrate their practice of learning clinical ultrasound within their own challenging clinical context. The eventual acceptance of the new reality by the trainees caused them to embrace the eLP's ability to facilitate their learning. Therefore, it seems that the active participation by the trainees from the onset and throughout the eLP's inception, design and construction phases increased their acceptance of the tool by creating a sense of co-ownership.

The focal theories changed evaluation outcomes that emerged from the interview data are illustrated in Table 5.3. The new communication channels enabled existing and created alternative feedback mechanisms linking the trainees to real patient experiences (Learner-Centred Design theory).[40,41] This means that any ultrasound scan can be captured for learning, irrespective of the hour or location, resulting in maximum trainee autonomy and control (Adult Learning theory and Flow Motivational theory).[45-48] The only variance to improved change was the eLP design's restriction in the use of social media discussions, which may result in reduced social development outcomes.

Unfortunately, the risk of breaching patient ethical principles in clinical practice (autonomy and non-maleficence) outweighs the social development learning benefits. However, involving the trainees in weighing the risks against the benefits improved their understanding of always considering patient ethics first when designing clinical training curricula and its delivery methods.

Instrumental theory change evaluation, for the adapted e-Learning Scorecard and Check and Connect theories from the same interview data, are presented in Table 5.4.[36,37,43] Trainees fully accepted the eLP's ability to create better access, therefore, improving their learning delivery and enhancement resulting in direct and indirect resource savings within the already low-resourced setting. The eLP's design, influenced by the learning requirements of the trainees within their setting's own challenges, created many new and unique innovations and knowledge applications (Table 5.4).

Table 5.3 **Evaluation of focal theories**

Focal theories evaluation	Good	Moderate	Poor
Learner-Centred Design theory	• Enhanced trainer feedback of trainee's scans of patients; • Feedback linked trainees' learning to real patient experiences; • Multiple novel passive and active communication channels.	• eLP facilitated access to informal peer support by linking trainees as "scanning buddies".	• eLP design dissuaded learner-led open online discussion groups for fear of divulging confidential patient information.
Adult Learning theory	• Maximised trainee autonomy (regulate their own speed of learning) where the eLP creates on-demand access from any devise and any location; • Clean, minimalistic, task specific, user interface design to reduce distractions from learning; • Multiple instruction options to cater for trainee diversity; • Asynchronous trainer feedback of scan via eLP solves the real world problem of having limited access to onsite trainer feedback to enable the completion of the required 65 scans within the two-year training period; • Multiple options at every scan capturing and upload juncture (asynchronous trainer feedback) to cater for varied trainee technical abilities; • Trainees experienced first-hand that improved scan skills augment their patient management ability, which motivates their learning; • Trainees directly involved throughout the design and construction process of the eLP.	• Closed (trainers and trainee password protected access) trainer-led (protecting patient ethical principles) collaboration online discussion groups focussing on scans that provide real learning value.	• Design limits the support of open social media for fear of patient confidentiality breaches and vulnerable patients with unique pathology to scan, be targeted by multiple trainees causing possible patient harm.
Flow Motivational theory	• The trainee's tasks are specified clearly under a primary heading and always accessible online; • eLP optimises feedback by enhancing traditional trainer-led feedback sessions and providing an alternative asynchronous feedback route by off-site trainers; • Trainees will control their own learning, via a consistent eLP tool that causes minimum distractions from the selected task at hand.		

Table 5.4 **Evaluation of instrumental theories**

Instrumental theories	Perspectives of measurements	Evaluation of e-learning platform (eLP)
E-learning Scorecard theory	Resource savings	• The eLP's ability to provide automated passive individual and group communication channels will improve time efficiency; • Trainees having instant access to task specific content from any location will reduce time spent on searching for information; • The eLP's booking system, where trainees can reserve personalised training sessions with trainers, will save both time and achieve a higher conversion rate; • Asynchronous trainer feedback to trainee submitted scans will create substantive direct and indirect cost savings by reducing travel time and costs; • Substituting a paper personal scan portfolio log with an electronic archived version will improve time efficiency and reduction of printing costs; • The eLP's ability to display the current status on a visual dashboard of the personal scan portfolio log of trainees will increase their efficiency to complete the remaining scans.
	Trainee acceptance	• All trainees immediately accepted the eLP's improved learning delivery of information, curriculum content, learning objectives and outcomes, and personalised instruction; • Trainees show a delayed acceptance to asynchronous trainer feedback of submitted scans only after realising that the eLP's booking system to reserve personalised training sessions will not solve the trainer access block on its own; • Acceptance by trainees were enhanced by being directly involved in the eLP's planning, design and development phases.
	Improved access to learning	• The eLP provided a profound improvement of the access of trainees to both learning delivery and learning enhancement by practically applying their training to real life scenarios they experience on a daily basis within their own clinical practices.
	Innovations and knowledge	• eLP providing multiple devise access (including mobile-learning) using multiple application variations; • Providing the option of downloading pre-selected content to enable use in locations without internet access; • Substituting the personal trainee paper scan portfolio log with an electronic version; • Creating a visual dashboard showing a snapshot of the current status of personal scan portfolios of trainees; • Creating an alternative asynchronous trainer feedback pathway for trainee submitted scans using structured, stratified, objective and subjective feedback methods with a the view to improve their scanning practice; • Multiple scan capturing, uploading and adding annotations options at each juncture of the upload pathway; • Visual benchmarking the scan quality expected from trainees and placing these images at multiple strategic locations to achieve maximum impact.
Check and Connect theory	Academic engagement	• The eLP tool created the capability to unblock the trainees' access to both learning delivery and leaning enhancement, which will eventually salvage their academic engagement.
	Behavioural, cognitive and affective engagement	• The eLP will restore behavioural, cognitive and affective engagement by enhancing the lesser resourceful, creative and inventive trainees' learning experience.

5.5.5 Reflection

5.5.5.1 Practical outcomes of the intervention

All stakeholders (ultrasound director and faculty), researchers and clients (trainees) accepted the new reality that the custom created eLPs (intervention) has the capacity to provide e-learning within the challenging low-resourced setting by enhancing our learning delivery efficiency. The involvement of participants from the onset (Susman and Evered diagnosis step) and being able to shape the eLP to solve their real world problem to provide proficient learning delivery, reinforced their sense of ownership. However, all participants soon realised the eLP's potential beyond its role as a sole distributor of learning content and information. Our focus thus immediately shifted towards integrating learning enhancement in the eLP design related to the low-resourced context and logistic challenges. The rich inductive contributions by the trainees, guided by their earlier (pre-eLP) experiences of academic disengagement, created the foundation for the learning enhancement component of the design of the eLP.

The addition of instrumental and focal theories provided the necessary oversight to enhance the design and provided guidance for Susman and Evered's steps by strictly keeping to participatory action research principles. Given that the first draft design of the eLP nearly ticked all of the components boxes of the instrumental and focal theories that evaluated learning delivery and design, the project also added unique context specific innovations and knowledge (Table 5.4). Theoretically, the concept of asynchronous off-site trainer feedback was conceived out of necessity to include trainees on the periphery of learning. However, little did we realise the design complexities required for the scan saving, transfer, upload and trainer feedback pathway to cater for the variance in the technical abilities of the trainees. The saying "a picture is worth a thousand words" was most relevant to our learning enhancement design, where strategically placed scan pictures that replicated the quality expected from our trainees acted as a passive benchmark and a constant reminder.

We realised the project still requires substantial work, especially repeat testing, to transform the eLP from first draft to full operational use. However, combining future Susman and Evered participatory action research cycles with adjusted and justified instrumental and focal theories to guide the next step interventions (eLP testing) will provide the necessary rigor to achieve eventual operational success.

5.5.5.2 Theories guiding the action plan

Although the Check and Connect instrumental theory identified academic disengagement as the diagnosis, with behavioural, cognitive and affective engagement reasonably intact, the instrument could not recognise the possible causes for the poor academic output (diagnosis) of the trainees.[36,37] An additional survey (trainees' perspective) and systematic review (logistic perspective) was necessary to identify the root causes of the academic disengagement of the trainees in our low-resourced context.

The strength of the eLearning Scorecard instrumental theory was its flexibility to allow study participants to adapt the four perspectives of measurement and analysis to the context of their e-learning project.[43] The e-Learning Scorecard instrument was practical, viewing the eLP as a single entity. The four perspectives of measurement and analysis was incorporated in the action planning step and also held the intervention accountable throughout the evaluation phase. Our study selected the root cause diagnosis of improving access to learning delivery, and preserving time and resource savings (given restrictions of our context) as two of the four measurement and analysis perspectives. Acceptance of the eLP design by the trainees was identified as a key performance indicator. It is expected that the trainees' acceptance will remain a constant measurement and analysis perspective throughout the small and large group testing phases. On reflection, we recommend the use of the e-Learning Scorecard instrumental theory to guide the design, construction and research of similar eLP projects.

The three focal theories used addressed the eLP design and research needs. Although many of the criteria of the three focal theories overlapped, they all made unique and special contributions. The Learner-Centred Design theory principals was successful in repositioning the trainee as the centre point of learning, during the design of the eLP.[40,41] Adult Learning theory principals improved the eLP end-user interface by keeping the design clean, minimalistic and void from any distractions, and catered for variable trainee technical skills.[45-47] The Flow Motivational theory principals removed many of the eLP design obstacles to learning. Trainees were better positioned to re-engage seamlessly by controlling the pace and flow of their learning, according to their needs and preferences.[48]

5.5.5.3 Limitations and future research

The interviews with the study sample, however small (n=7), represented the full study population as defined by the inclusion criteria. The first author's insider perspective and orientation towards the other study participants is clearly stated in the manuscript and

fitted well with the participatory action research design and provided expert interpretation of the data analysis.

This study completed a single Susman and Evered participatory action research cycle to guide the design and construction of the eLP up to first draft stage. Further investigation, by means of subsequent Susman and Evered participatory action research cycles, should focus on validating the draft eLP's usability, learning delivery and enhancement, initially by small peer groups followed by more comprehensive evaluation via larger user-based groups.

Small peer review groups (made up of clinical ultrasound faculty) need to internally validate the eLP's content management and distribution. It is recommended that peer reviewing e-learning tools should be considered and eventually integrated as an additional faculty activity and scholarly requirement. It is expected that future research will be needed on faculty adoption and their specific development needs during the eLP validation, evaluation and roll-out phases.

5.6 Conclusion

The study participant collaborations led to real practical and social change by creating a custom-designed eLP that changed the way clinical ultrasound trainees learn in our low-resourced context. The change process concluded that the diagnosis of academic disengagement of our trainees was caused by learning delivery block. Action planning proposed the design, construction and implementation of an eLP intervention as part of a blended learning approach to reposition the trainees at the centre of learning with the aim to unblock their learning delivery. Evaluation revealed that the attitudes of the study participants changed from being sceptical to acceptance and eventually adoption of their new reality. This was facilitated by the eLP's ability to provide improved learning access via alternative pathways. Reflection focused on the eLP's practical outcomes, changes experienced by participant groups, future testing and the effectiveness of the theories used. Early inclusion of the trainees as study participants led to their early acceptance of the eLP's ability to first improve their learning delivery, then restore their academic engagement, and eventually their learning enhancement, which should finally reflect in improved credentialing success rates.

5.7 References

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Chapter 6

Summary, Conclusions and Recommendations

6.1 Results summary

Mutual collaboration between study participant groups (researchers, trainees and e-learning developers) identified and embarked on alleviating the problem of low credentialing success in Cape Town's clinical ultrasound training programme by adhering to Susman and Evered's iterative and reflective cycle steps to implement change and learn from it (Chapter 5, Figure 5.1).[1]

Findings from Susman and Evered's *problem diagnosis step* indicated that the poor credentialing success of the trainees was attributed to academic disengagement. The root cause for their academic disengagement was learning delivery failure. From the perspective of the trainees, limited time available in their busy schedules to train, limited access to personalised trainer feedback and technical difficulties to save scan images for indirect feedback, reduced their learning delivery. From a logistic training programme perspective, long distance training, using multiple training sites and having fewer resources to train, impeded the trainee learning delivery.

Susman and Evered's *action planning step* focused on restoring learning delivery. The immediate plan was to consolidate the current training capacity by adding active, passive, individual and group communication channels regulated via a novel e-learning platform (eLP) to improve direct trainer-led feedback and instruction (Chapter 4, Table 4.2). The long-term plan would provide trainees access to an alternative pathway to receive asynchronous trainer feedback on submitted scans via the eLP, resulting in less missed training opportunities. The alternative feedback pathway would assist trainees to complete the task of submitting their 65 personal log scans within the specified two-year time limit.

Themes analysed from the interviews conducted with the trainees, contributed to the eLP design and construction up to the first draft stage (Susman and Evered's *intervention step*). The themes supported most learning delivery and learning enhancement elements

for e-learning. In turn, both the e-learning elements and themes were supported by Adult Learning, Motivation and Learner-Centred Learning theories (Chapter 4, Figure 4.2).[2-7] The underpinning of the eLP design by these theories would strengthen learning delivery and learning enhancement even further.

Susman and Evered's *evaluation step* concluded that learning delivery improved while maintaining context-specific resource savings (Chapter 5, Table 5.3). All the study participants accepted the new reality of incorporating e-learning as part of a blended learning approach. The study participants also believed that their participation throughout Susman and Evered's cycle steps, strengthened their acceptance of the changes made. New innovations and knowledge were also created during the change process (Chapter 5, Table 5.4).

Susman and Evered's *reflection step* reported that the study participants' initial perception of the eLP, as a sole distributor of information, changed as they became fully immersed in the study. Eventually they realised the potential of the eLP being a conduit to deliver learning, thereby creating learning enhancement by enabling multilevel interactions between trainers, trainees, curriculum content and information, ultimately restoring academic engagement that should reflect in improved future credentialing outcomes.

6.2 Discussion

6.2.1 Limitations and critical appraisal of the study results

The study results' emphasis on quality learning delivery, supported by a fit for purpose eLP design, to enhance learning, by using Susman and Evered's participatory action research steps, were context and perspective specific and would therefore need to be validated in different settings. The study findings will also need to be validated beyond clinical ultrasound training. The survey's relatively low response rate (41,3%) may have introduced responder and non-responder biases to the root causes identified from the trainees' perspective that contributed their academic disengagement. The low yield of the systematic review (six studies) and their observational, retrospective and cross-sectional study designs together with varying validity, undermined direct comparison of the included training programmes credentialing success rates and to a lesser extent the critical analysis of the logistical root causes that also contributed to the trainees' academic disengagement.

Among the study's logistical limitations were the trainees' inability to attend the e-learning developer's meetings due to their busy clinical schedules where they would have been able to directly influence the e-learning construction according to their needs and preferences. Instead, the primary author functioned as an intermediary to transfer their design ideas. The timeous process of data collection, analysis, and the eventual transfer to eLP design and construction was not always a linear process for all the design themes analysed from the interviews and meetings. The effect sometimes resulted in fragmented evaluation of the eLP components which in turn fuelled further time delays.

Limited funds held the study hostage at various stages during its development causing multiple interruptions in eLP construction to the specifications of the draft design as informed by the study themes. Only when funds became available to reimburse the e-learning developers did the eLP construction proceed. To overcome the challenge the eLP design and construction elements were demonstrated by storybook illustrations to expedite Susman and Evered's evaluation step of the study.

As primary investigator, my interpretivist paradigm, relativist ontological and subjectivist epistemology perspectives had a bearing on the results of this study. My relationship and orientation with the rest of the study participants had a direct influence on the interview data and analyses. The results were produced within our unique low-resourced setting and are therefore context specific. At first, my insider and stakeholder orientation might be viewed as a potential weakness. However, having many years of experience as a clinical ultrasound clinician, educator, researcher and leader provided the study with an expert overview. Understanding how the results were produced and my interpretation thereof should be viewed via my own perspectives, relationships, orientations and context exposures, which have been stated clearly throughout the dissertation manuscript.

Other modes of action research were considered at first. In technical action research, the researcher identifies the problem and the specific intervention.[8] An authoritative person (or group) with particular qualifications and experience who is usually regarded as expert(s) will often instigate the project. The project is product-directed (instead of person-directed) and communication flow is mostly conducted between the facilitator and the rest of the study group participants.[9] The knowledge produced is often more predictable, product-centred and essentially deductive, often concentrating on validation and refinement of existing theories.[8] We finally decided on a participatory action research approach to enable the involvement of the trainee group (most

adversely affected by the poor credentialing outcomes) from the onset to solve their problem, acting as equal collaborators, by instigating the intervention and creating social change derived from critical reflection, and learning from it.[9] Communication flow was unimpaired between each member of the collaboration groups and the project facilitator (primary investigator).

The appraisal of our participatory action research study matched all of the key elements of Chatteron[10]:

- The study brought about change by engaging all groups to work towards this change.
- The study was unique, to our particular context, revolving around the unique needs within a particular group of people (trainees).
- The study emphasised teamwork and active collaboration, where researchers and participants work together to analyse a problem situation (low credentialing rates) and generate actions (design an eLP) to solve the problem.
- The study followed an iterative process, involving actions and constant reflection.
- It created awareness among participants about their current situation and they eventually need to take action to create positive change.

At first glance, the trainee interview group might seem small (n = 7). Yet, clearly specified inclusion criteria defined the sample to represent trainees who were affected adversely by the learning delivery block and were active participators in the clinical ultrasound training programme over the last two years. The sample represented the study population in full.

The interpretivist paradigm and qualitative methodological approach of this study aimed at creating meaning instead of associations and causality. Therefore, different measures to ensure rigor were used throughout. Member checking was used for all seven interviews with the trainees. Only one suggested changes to their transcript. A reflective journal was kept throughout the study that was regularly updated. Early transcriptions and exploration of the interview content allowed amendments of the interview schedule before the next interviews commenced resulting in improved accuracy. The first exploratory interview step and first level analysis allowed us to construct a more accurate interview schedule for the second step semi-structured interviews. The data analysis strictly followed Braun and Clark's eight stages of thematic analysis.[11] A codebook was kept throughout the analysis process and regularly updated. A strict audit trail was kept during the analysis process. Data analysis was only ceased when both researchers were satisfied that no more themes would emerge from the data. Both inductive and deductive analyses were applied. Instrumental and focal theories were used throughout

Susman and Evered's cycles to improve practical outcomes and scholarly benefits.[12] All theories used were thoroughly reflected upon for their appropriateness and the way they informed the practical outcomes of the intervention.

6.2.2 Unanswered questions and future research

A single Susman and Evered and participatory action research cycle was completed to guide the design and construction of the eLP up to its first draft stage. Validation testing led by a small group of clinical ultrasound faculty followed by large user-based group evaluation will still be needed to transfer the eLP from its current draft format to readiness for everyday use. We recommend using the same Susman and Evered's cycles, but to adjust the action research mode and supporting theories to align seamlessly with the respective eLP validation and evaluation processes. During this phase, the technical action research mode could be a better fit for reasons mentioned in the previous section. Appropriate and justified instrumental and focal theories should emerge from subsequent Susman and Evered's cycles of enquiry data to improve rigor.[12]

Small peer review groups should internally validate the draft eLP by verifying the content and how it is managed and distributed via different devises (such as, mobile devices). Additional parameters should be considered during the verification process. Usability includes the ease of navigation through the online material, conduciveness of the appearance to educational activities and if the interactive education is user-friendly and appropriate. We expect the non-traditional instructional activity of regular eLP peer review to become a scholarly requirement for future faculty. The promotion, development and adoption of future faculty members to become proficient in this new task will also create ample research opportunities.

Large user-based groups should evaluate the eLP after the validation testing is complete. A technical action research approach should provide a robust structure (via Susman and Evered's cycles) to conduct the evaluation testing and extract maximum scholarly benefits.

Outcome evaluation of the eLP interventions creates additional research potential after all the testing phases are complete and the platform becomes fully operational. Kirkpatrick's evaluation framework that has been specially adapted to health care education is one such model that evaluates e-learning interventions. The Kirkpatrick model defines four levels of evaluation based on outcomes (Figure 6.1):[13]

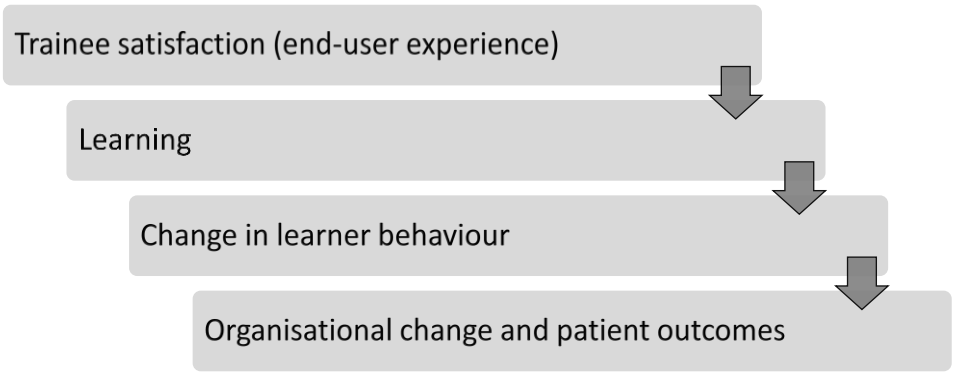

Figure 6.1 **Kirkpatrick's four levels of evaluation based on outcome**

The first level evaluation (trainee satisfaction) should be measured during the large trainee user-based evaluation of the eLP as described earlier. The second and third level evaluation should measure the learning enhancement that occurred after learning access has been restored by introducing an effective eLP. The true impact of the eLP on patient outcomes and subsequent organisational changes will be difficult to measure for all the confounders present (low-resourced health system complications) that may also influence patient outcomes. Improving the outcomes of the first three levels should eventually reflect as an increase of the credentialing success rates of the clinical ultrasound trainees. However, only if successful credentialing represents real operator skill competency will the fourth level (patient outcomes) improve.

We expect that the role of the clinical ultrasound trainer will change from being part of the problem to forming part of the solution after the implementation of eLP. Many of the trainees interviewed reported that trainers were seldom available to provide personal instruction or feedback (burdened by their own heavy workload), therefore, contributing to the learning delivery block they experienced. The post eLP intervention will change the trainer's paradigm from a sole supplier and distributor of content to becoming a facilitator of learning and regular assessor of operator competency via alternative asynchronous feedback pathways. Additional education and mentorship support will be required to facilitate their learning of new skills (e.g. online trainee feedback) and assist trainers to evolve into their new roles.[14] The trainer's transformation and re-invention processes will also create new research opportunities.

We foresee that some of the results of this study may be transferable to assist with an eLP design for clinical ultrasound training in different resourced settings, depending on the degree of trainee disconnection experienced. Fewer results will be transferable to other emergency medicine skills and medical specialties' eLP design. However, some of our

theory could be used as a starting point for a practical skill eLP design, when integrated with the particular uniqueness of the curricula and the context of the trainees as part of a well devised needs analysis plan.

6.3 Recommendations

According to the outcomes of the study, the following recommendations can be made:

Problem diagnosis

1. Use instrumental theories to enable an independent problem diagnosis in clinical ultrasound training programmes that under-perform so the investigator can create an action plan based on a detailed and accurate diagnosis.[1,2,15,16]

Action planning

2. Initially create a short-term action plan that consolidates existing training capacity by utilising the e-learning platform's multiple communication channels to provide trainees with immediate on-demand access to training programme information, learning outcomes, expectations, content and to arrange personalised training sessions via an online booking system.[1,12]
3. This should be followed by a long-term action plan that provides alternative pathways for trainees to access asynchronous trainer feedback of their uploaded scan archives via the e-learning platform to enable their task completion based on appropriate and justified focal e-learning education theories.[1-7,12]

Intervention (e-learning design and construction)

4. Provide trainees with multiple pathways (flash storage, cloud storage and personal mobile phone camera routes) and options at every juncture to capture, archive and upload scans via desktop and mobile devices (browser and custom applications) to accommodate trainee technical skill variances and personal preferences when uploading scans to the e-learning platform for asynchronous trainer feedback that enables interactive learning and task completion from the patient's bedside.
5. Trainers should provide stratified, structured, detailed and positive asynchronous feedback that includes both objective (Likert scale) and subjective (text box comments) components and focuses on improving the trainees' clinical ultrasound skills and practice.[17]

6. The placement of a highly visible dashboard that shows a visual snapshot of the trainees' completed and required scans and high quality benchmarked scans pictures, including annotations, at multiple strategic locations on all scan upload pathway junctures, to passively remind trainees of the minimum quality standards that are expected from them.

Evaluation

7. The use of appropriate and justified instrumental and focal theories to assess the actual changes experienced by all participant groups, if the problem has been sufficiently solved, if the e-learning platform changes that were expected, were achieved and to explain the reasons behind any variances measured.[1-7,2,15,16,18]

Reflection

8. Reflect on the practical and the study participant groups' changes that have taken place, the learning created from the change process, and the strengths, weaknesses and appropriateness of the instrumental and focal theories that were used to enable change.[1,12]

Next steps

9. Faculty-led small peer group validation testing, followed by larger user-based group evaluation of the current draft e-learning platform by using an appropriate action research approach, underpinned by Susman and Evered's cycles of enquiry and justified instrumental and focal theories should be undertaken next, to prepare the e-learning platform for everyday use.[13]
10. Investigate the changed paradigm of the trainers from a supplier and distributor of learning content to a facilitator of learning and assessor of learning competency (such as indirect feedback via an e-learning platform interface) and their evolvement into their future roles.[14]

6.4 Personal reflection

There is no doubt that e-learning has already achieved enough momentum to dominate future education. However, the transferability of the study results, will be a key factor to accelerate its further development. Unfortunately, many results are presented in descriptive and evaluation format that undermines transferability and therefore has the potential to fragment educational literature. An urgent paradigm shift that focuses on reporting theory-led instead of technology-led results is urgently needed.[19] A quote from

Mark Nichols, an e-learning consultant at Universal College of Learning in New Zealand, explains the importance of theory in e-learning:[20]

> *Practice-based research can be likened to the branches of a tree. The parts that are readily visible are most easily appreciated. Theoretic principles can be likened to the roots; they do not provide any practical things for people like shade or fruit and neither are they aesthetically pleasing. However, it is the root system that determines the health of a tree and also the extent to which it can grow. Unless attention is given to e-learning theory, e-learning practice cannot develop fully. Without further debate and development in the theoretical underpinnings, we will be left with bonsai e-learning.*

Our study was successful in using many well-known existing theories with justified minor adjustments to adapt them to our low-resourced setting, while still adhering to their original meaning.

The Check and Connect theory successfully diagnosed a unique group of learners' (Emergency Medicine specialist Clinical Ultrasound trainees) disengagement in a low-resourced setting.[15,16] However, additional investigations from a logistic and trainee perspectives were necessary to establish the root causes for the academic disengagement experienced, which added to the e-learning theory root system.

Applying the e-learning Score Card theory to our study was beneficial. The four perspectives of measurement were specially adapted to evaluate our e-learning platform design in the low-resourced context. The e-Learning Score Card theory's unique measurement criteria provided our study with a thorough evaluation. It is expected that the e-Learning Scorecard theory's adjustable theoretical framework will be externally valid in evaluating e-learning platform designs in different settings, if the measurement criteria chosen are based on the results of the preliminary studies and justified by evidence. The four measurement criteria that the current study used would also expand the current root system.[18]

Six themes emerged during the trainees' interviews by means of the inductive thematic analysis that corresponded with Learner-Centred Learning, Adult Learning and Motivation theories and their influence on restoring learning delivery and enhancement in our setting (Chapter 2, Figure 2). The same three theories that were applied to our e-learning platform's design were thoroughly utilised for deductive analysis during each of Susman and Evered's steps. Although some of the content overlapped, each of the three theories made unique contributions and supplemented the e-learning platform design, which added more roots to the system.[2-7]

The study also raised interesting hypotheses. Unfortunately, not enough hypotheses were created that could be applied to a particular phenomenon and potentially a new theory. Logistic failures (long distance training, using multiple centres, allocating fewer resources) and barriers identified by the trainees (severe time stress, limited access to trainer instruction and feedback) were some of the hypotheses raised that contributed to the learning delivery block of the trainees. Visual benchmarking as a group hypothesis theme, supported by benchmarked quality images of scans at strategic upload locations, dashboard of the personal portfolio log of trainees, and visual diagrams to explain training programme information, guidance and curriculum content are new e-learning platform design hypotheses unique to clinical ultrasound. Although the significance of all of the new hypotheses still needs to be verified by further research, they have the potential to develop in future theories that may expand the root system even further.

6.5 Conclusion

Successful collaboration between study participant groups, as equal partners, led to real practical and social changes by creating a custom designed e-learning platform that transformed the way clinical ultrasound trainees learn in our low-resourced context. The change process concluded that our clinical ultrasound trainees' academic disengagement diagnosis was caused by learning delivery block.

Action planning proposed the design, construction and implementation of an e-learning platform intervention as part of a blended learning approach to reposition the trainees at the centre of learning with the aim to unblock their learning delivery. Evaluation found that the attitudes of study participants changed from sceptical to acceptance and eventually adoption of their new reality facilitated by the e-learning platform's ability to provide improved learning access via alternative pathways.

Reflection focused on the practical outcomes of the e-learning platform, the changes experienced by participant groups, future testing and the effectiveness of the theories used. The early inclusion of the trainees as study participants expedited the acceptance of the e-learning platform's ability to first unblock their learning delivery, then restore their academic engagement, and eventually culminate in their learning enhancement, which should reflect in improved credentialing success rates.

6.6 References

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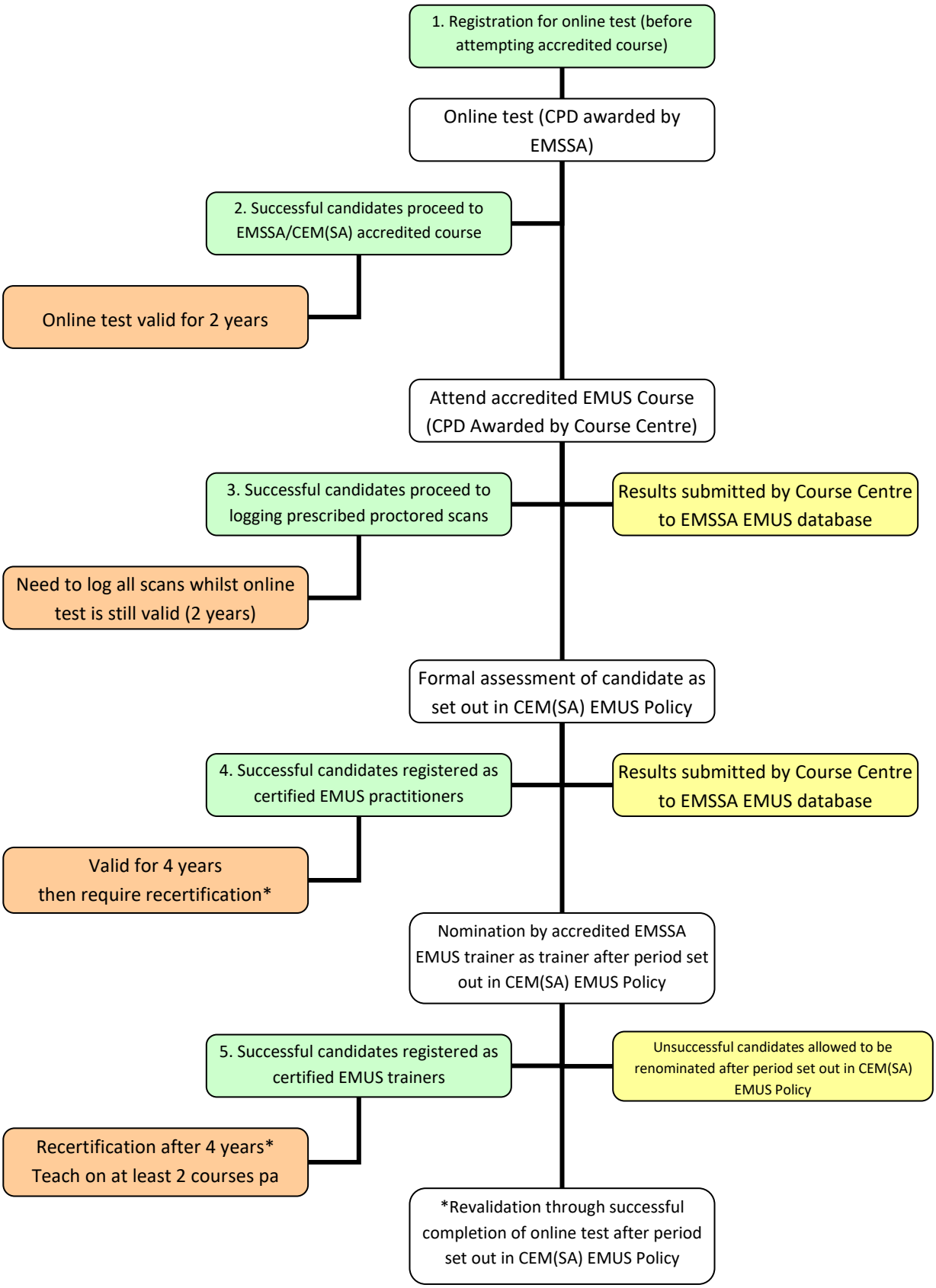
Appendix A: CEMSA CUS training pathway



Appendix B: Online survey questionnaire

- **Introduction:** Thank you for sharing your experiences by completing this survey! You are included in the study by virtue that you completed the Cape Town introductory ultrasound course from 2009 to 2013 and therefore entered the clinical ultrasound training programme. Irrespective of whether you successfully completed your training or not, your answers are valuable to us so we can establish which barriers you encountered during your training experience. Your assistance will provide us with possible solutions to reduce these barriers for future trainees.
- **Instructions:** Please open the link to SurveyMonkey© on your invitation e-mail. Please complete all 13 questions in the survey by providing one answer per question unless directed otherwise. Please do not leave any questions unanswered.
- **Ethics:** The Health Research Ethics Committee at Stellenbosch University approved the study (Ref: N13/04/056). By completing the survey, you will imply that you provided consent to participate in the study. No personal or identifying information will be collected to protect your confidentiality. The survey will de-identify all responses. All data will be protected by a password to ensure its integrity.

1. **What was your highest academic qualification <u>at the time when you attended the ultrasound introductory course</u>:**
   - Primary Graduate degree (e.g. MB ChB)
   - Post-graduate diploma (e.g. DA, Dip PEC)
   - Post-graduate Master's degree (e.g. M Med, M Phil)
   - Post-graduate specialist college qualification (e.g. FCP, FCS, FCEM)
   - Doctorate degree (e.g. PhD)
   - Other- please specify:_____

2. **What is your <u>current</u> highest academic qualification?**
   - Primary Graduate degree (e.g. MB ChB)
   - Post-graduate diploma (e.g. DA, Dip PEC)
   - Post-graduate Master's degree (e.g. M Med, M Phil)
   - Post-graduate specialist college qualification (e.g. FCP, FCS, FCEM)
   - Doctorate degree (e.g. PhD)
   - Other- please specify:_____

3. **What was your job title <u>when you completed the introductory course</u>?**
    - Intern
    - Community Medical officer
    - Medical Officer
    - Junior Registrar (Year 1-2)
    - Senior Registrar (Year 3-4/5)
    - Subspecialist senior registrar
    - Junior consultant with less than 5 years' experience
    - Senior consultant with more than 5 years' experience
    - Subspecialty consultant
    - Other- please specify:_____

4. **What is your <u>current job title</u> at the time of completing this survey?**
    - Intern
    - Community Medical officer
    - Medical Officer
    - Junior Registrar (Year 1-2)
    - Senior Registrar (Year 3-4/5)
    - Subspecialist senior registrar
    - Junior consultant with less than 5 years' experience
    - Senior consultant with more than 5 years' experience
    - Subspecialty consultant
    - Other- please specify:_____

5. **What was your clinical area of work <u>at the time when you attended the course</u>?**
    - Emergency Medicine
    - Internal Medicine
    - Surgery
    - Paediatrics
    - Intensive care
    - Anaesthetics
    - Family Medicine
    - General Practitioner
    - Other- please specify:_____

6. **Which clinical area are you working <u>in at present</u>?**
    - Emergency Medicine
    - Internal Medicine
    - Surgery
    - Paediatrics
    - Intensive care
    - Anaesthetics
    - Family Medicine
    - General Practitioner
    - Other- please specify:_____

7. **Years of clinical experience after completion of your MB ChB (or equivalent) <u>at the time of the ultrasound course</u>:**
    - 2 years or less post primary medical qualification
    - 3-5 years post primary medical qualification
    - 6-9 years post primary medical qualification
    - More than 10 years post primary medical qualification

8. **Type of facility where you are <u>currently working</u> most of your clinical time:**
    - Primary Health Care (Community Health Centre, Clinic)
    - District hospital
    - Regional hospital
    - Tertiary hospital
    - Private practice
    - Non-Clinical (Management, Research, Education, outside medicine)
    - Other-please specify:_____

9. **Geographical area where you <u>currently work</u> most of the time:**
    - Western Cape
    - Eastern Cape
    - Northern Cape
    - Kwa-Zulu Natal
    - Gauteng
    - Mpumalanga
    - Limpopo
    - Free State
    - North-West
    - Other country-please specify:_____

10. **Have you successfully completed the clinical ultrasound credentialing process and obtained certification**
    - Yes
    - No

11. **The following are options of perceived barriers that made it difficult for you to complete your credentialing. Please <u>RANK them in the order of importance</u> (1 to 8) that you feel may have affected you the most.**
    - I never planned to complete the ultrasound credentialing process (log the required scans and final assessment) <u>at the time when I attended the ultrasound introductory course</u>.
    - Limited access to ultrasound machines to log my scans
    - Limited access to appropriate patients to practice my scans and log them
    - Difficulty to gather certain prerequisite positive scans due to the scarcity of their pathology (example: Positive abdominal aorta aneurism scans)
    - Time constraints due to other commitments and conflicts
    - Difficulty to save my scanned images for log purposes for a delayed review by a credentialed trainer
    - Limited access to a credentialed trainer to approve my log scans on site and provide real time feedback

- Any obstacles not on list (please add and rank them below)

  _____

  _____

  _____

12. **How often do you use ultrasound in your daily clinical practice to enhance your clinical decisions (applicable to real patient management decisions)?**
    - I never perform any scans on my patients
    - 2 or less scans per week
    - 3-10 scans per week
    - 11-20 scans per week
    - More than 20 scans per week

13. **If you have not credentialed yet, are you planning to challenge the ultrasound exam in the future?**
    - Yes
    - No
    - Not applicable

Appendix C: Exploratory interview schedule

Phase 1 interview schedule (exploratory and unstructured)

- **Tell them**: Thank you for taking time out from your busy schedule to do this interview.
- **Inform them**: That their identities will be kept confidential throughout the investigation.
- **Let them**: Read and sign the informed consent form if they agree to do.
- **Inform them**: An analysis of Cape Town's credentialing outcome showed that only 1 in 5 trainees successfully credentialed from 2009 to 2015. Our study's aim is to improve future outcomes.
- **Gambit:** As an active participant in the training programme, I would value your personal opinions on how we can improve your/the credentialing success in lieu of the specific challenges we face.
- All your answers will be kept anonymous and confidential.
- Remember to thank them after the interview and also formally by e-mail.
- Send them a transcript for member checking within 1-week after the completion of the interview.

1. In your personal opinion, how can we improve your/the future credentialing success of our clinical ultrasound training programme?

2. What do you think trainers can do to improve success?

3. What do you think trainees can do to improve success?

4. How do you personally think a purpose built e-learning platform (eLP) can improve your credentialing success?

5. Anything specific the e-learning platform (eLP) must do for you to make your/the task of credentialing easier? (Suggestions)

6. Anything else you want the e-learning platform (eLP) to do for you beyond improving your/the credentialing success?

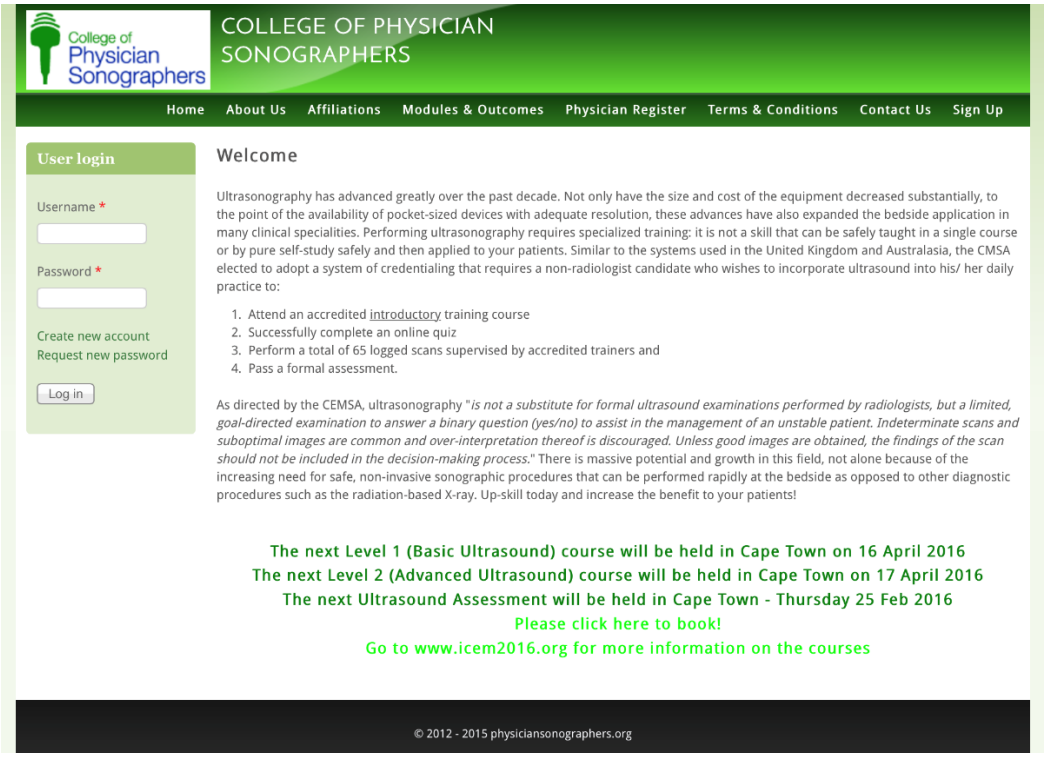
7. In your opinion are there any design suggestions you have that we can incorporate when we design an e-learning platform (eLP) to assist you?

Appendix D: Semi-structured interviews

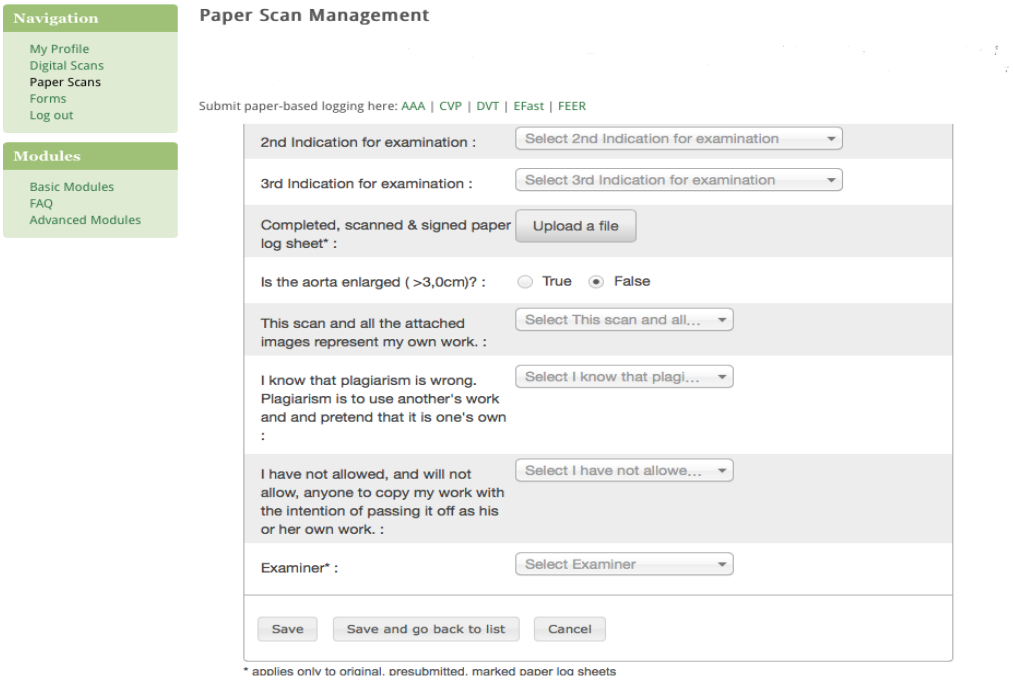
Themes (first level analysis)	Semi-structured (Step 2) interviews questions schedule
Communication improvement	1. In your opinion what communication threads should to be included in a novel e-learning platform (eLP)? 2. Do you have suggestions for alternative communication pathways (both via or separate from the eLP)?
Educational content	3. What clinical ultrasound teaching material should be included in the eLP? 4. Except for teaching material, anything else clinical ultrasound related we should also include?
End-user (trainee) eLP interface	5. How do you prefer the eLP interface should look like? 6. Any other suggestions regarding the interface and how it should function? 7. Any suggestions on how we can achieve this?
Ultrasound images upload and transfer	8. Any suggestions on how to upload ultrasound images to the eLP? 9. Any alternative suggestions?
Trainer feedback	10. Any suggestion on how you wish to receive trainer feedback for your uploaded images via the eLP? 11. Which specific criteria do you wish to receive feedback on?
Add-ons	12. Any add-ons we should consider to include in the eLP?
Quality assurance	13. Any suggestions of quality assurance measures we should institute via the eLP regarding the trainees? 14. Any suggestions of quality assurance measures we should institute via the WBLP regarding the trainers?

Appendix E: Examples of e-learning platform design

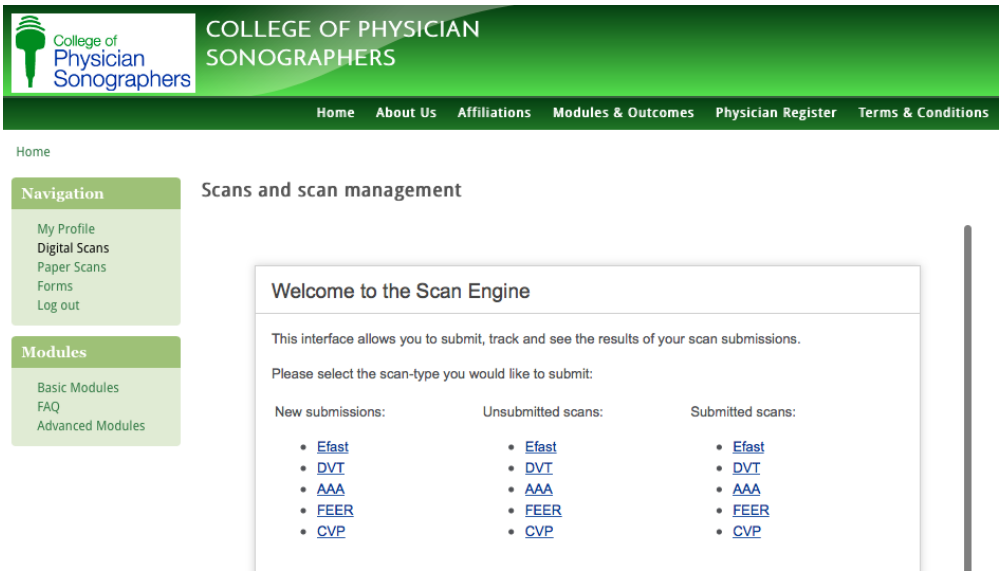
1. Theme 2: Example of accessing multiple e-learning communication channels by using the home page (refer to page 49, table 4.2)



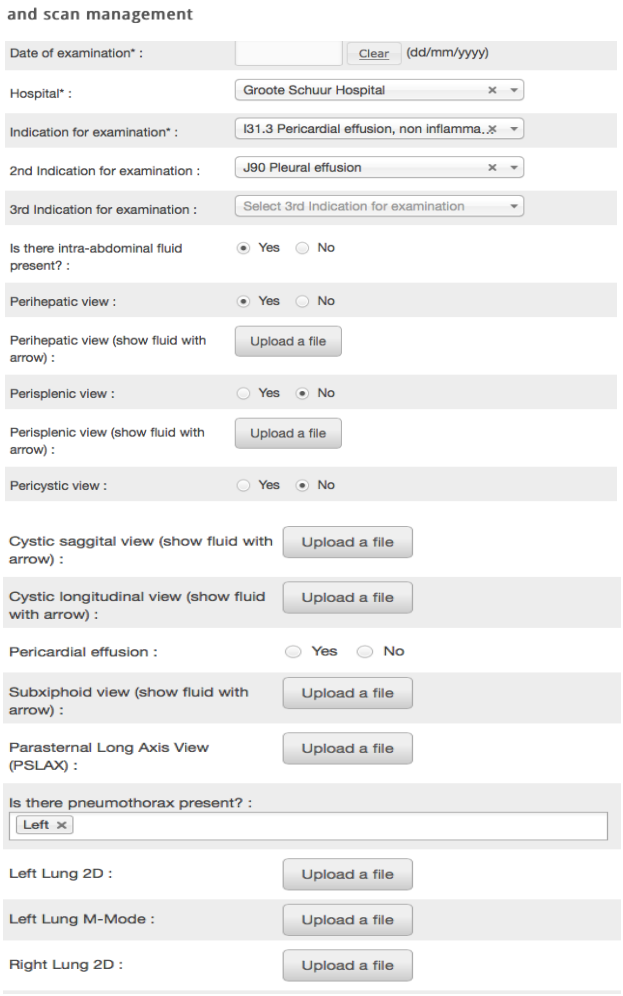
2. Theme 3: Example of main menu for trainees to access direct trainer instruction and logging of the experience with hand signed paper scans

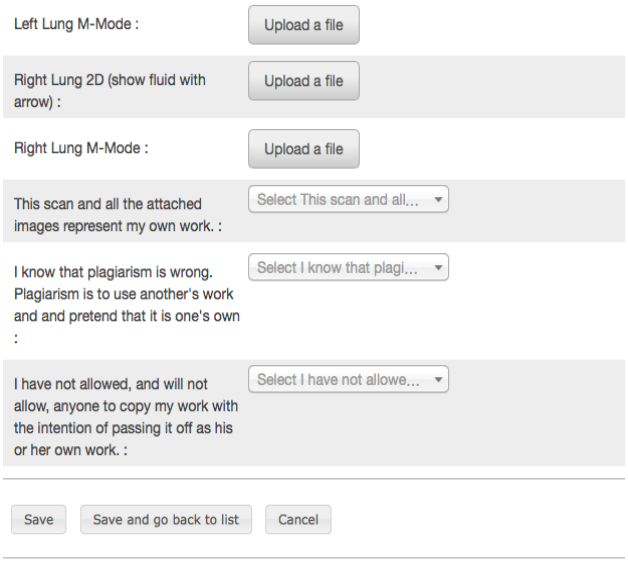


3. Theme 3: Example of main menu for submitting archived scan images for asynchronous trainer feedback



4. Theme 3: Example of trainee interface for submitting archived scan images for asynchronous trainer feedback from any devise



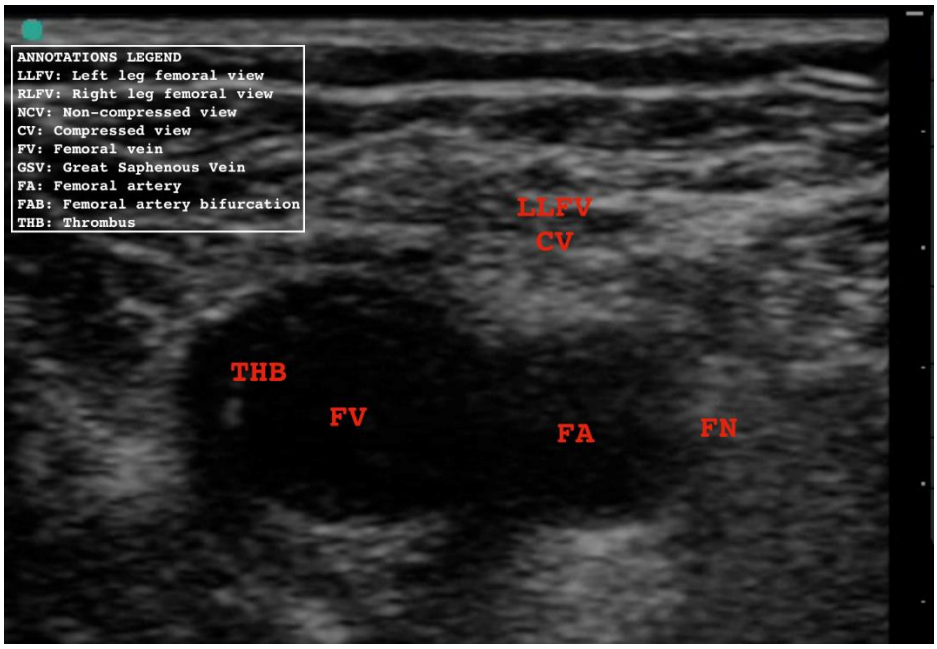


5. Theme 3: Example of trainee's asynchronous trainer feedback scan log to show progress of trainer feedback

Show 25 entries Search:

Submission date	Date of examination	Indication for examination	Status
07/07/2014 - 16:09	20/06/2014	I79.0 Aneurysm of aorta in clinical disease classified elsewhere	accepted
11/06/2014 - 13:08	11/06/2014	J90 Pleural effusion	accepted
11/06/2014 - 16:29	11/06/2014	I31.3 Pericardial effusion, non inflammatory	accepted
18/06/2014 - 20:14	18/06/2014	I31.3 Pericardial effusion, non inflammatory	submitted
28/05/2014 - 12:28	28/05/2014	J90 Pleural effusion	submitted
29/05/2014 - 12:12	29/05/2014	J90 Pleural effusion	submitted
29/05/2014 - 12:19	28/05/2014	Z00.01 Encounter for general adult medical examination with abnormal findings	rejected
29/05/2014 - 15:37	29/05/2014	J94.2 Haemothorax	submitted
29/05/2014 - 15:50	29/05/2014	I31.3 Pericardial effusion, non inflammatory	rejected
29/07/2014 - 14:58	29/07/2014	I31.3 Pericardial effusion, non inflammatory	accepted
31/08/2016 -	31/08/2016	K66.1 Haemoperitoneum	submitted

6. Theme 4: Example of visual benchmarking of the scan quality expected (including annotations) from the trainees at the point of image upload for asynchronous trainer feedback



7. Theme 4: Example of visual benchmarking of the trainees scan log to provide them with a snapshot of their current log status